A Summary of Current Program and
Preliminary Report of Progress



# COTTON AND COTTONSEED RESEARCH

of the

United States Department of Agriculture
and related work of the
State Agricultural Experiment Stations

This progress report is primarily a research tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs. The summaries of research progress include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C. 20250

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The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

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## ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First, there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

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## SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the U.S.D.A. program and progress for the following commodities and subjects:

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A copy of any of the reports may be requested from James F. Lankford, Executive Secretary, Cotton Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250.

## INTRODUCTION

This report deals with research on cotton and cottonseed. It does not include extensive cross-commodity work, much of which is basic in character, which contributes to the solution of not only cotton and cottonseed problems, but also to the problems of other commodities. Progress on cross-commodity work is found in the organization unit reports of the several divisions.

The report is presented under three main headings: Farm Research; Nutrition, Consumer, and Industrial Use Research; and Marketing and Economic Research. There is also a breakdown by problem areas as shown in the table of contents. For each area there is a statement of (1) the Problem, (2) USDA and Cooperative Program, (3) Program of State Experiment Stations, (4) a summary of Progress during the past year on USDA and Cooperative Programs, and (4) a list of Publications resulting from USDA and Cooperative Programs.

Cotton and cottonseed research is supported by (1) Federal funds appropriated to the research agencies of the U.S. Department of Agriculture, (2) Federal and State funds appropriated to the State Agricultural Experiment Stations, and (3) private funds allotted, largely by cotton and cottonseed industries, to research carried on in private laboratories or to support of State Station or USDA work.

### Research by USDA

Farm research in the Agricultural Research Service dealing with cotton and cottonseed comprises investigations on breeding, genetics, diseases and variety evaluation, weed and nematode control, insects, cotton planting, fertilizing, harvesting, handling operations and equipment, pest control, and cotton ginning. It is carried out in the following divisions: Crops, Entomology, and Agricultural Engineering. The work involves 179 professional man-years of scientific effort.

Nutrition, consumer and industrial use research in the Agricultural Research Service is directed toward improved methods and equipment for milling processes, textile finishing; development of new and improved uses of both cotton and cottonseed, and increasing the consumer acceptance of cotton textiles and of food products containing cottonseed. The work is done by the Southern Utilization Research and Development Division, New Orleans, Louisiana; the Clothing and Housing Research Division; and under contract with state and foreign country laboratories, and in cooperation with the industry and other organizations mentioned under programs for each research area. The work involves 209 professional man-years.

Marketing and economic research is done in three services. Marketing research in the Agricultural Research Service dealing with cotton and cottonseed is concerned primarily with the physical and biological aspects of assembly, packaging, transporting, storing and distribution from the time the product leaves the farm until it reaches the ultimate consumer. It is carried out by the Market Quality, and Transportation and Facilities Research Divisions.

The Cotton and cottonseed research in these divisions involves 20 professional man-years of scientific effort. Economic research conducted in the Economic Research Service deals with marketing costs, margins, and efficiency; market potentials; market structure, practices, and competition; outlook and situation; and supply, demand, and price. Consumer preference studies are carried out by the Statistical Reporting Service. Research in cooperative marketing is conducted by the Farmers Cooperative Service. The cotton and cottonseed research in these services involves 21 professional man-years of scientific effort.

## Interrelationships among Department, State and Private Research

A large part of the Department's research is cooperative with State Experiment Stations. Many Department employees are located at State Stations and use laboratory and office space close to or furnished by the station. Cooperative work is jointly planned, frequently with the representatives of the producers or industry affected participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators which frequently includes resources contributed by the interested producers or industry.

Including both cooperative and State Station projects, cotton and cottonseed research is in progress in 18 of the 53 State Agricultural Experiment Stations. The types of work to which the largest amount of effort is devoted include cotton culture, breeding, diseases and variety evaluation.

Industry's participation in cotton and cottonseed research is sponsored largely by commercial seed breeders, chemical companies, farm equipment manufacturers, cotton textile manufacturers, textile schools, manufacturers of finishing agents, textile finishers, textile research institutes, textile chemical manufacturers, processors, department stores, mail order houses and manufacturers, and cotton producers.

## Examples of Research Accomplishments by USDA and Cooperating Scientists

Nucleic Acids in the Cotton Plant. The concept of the involvement of nucleic acids in hereditary transmission of characteristics has been widely proposed. Research on the specific role of DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) is underway in many laboratories including those solely or principally crop plant oriented. Of considerable interest is the recent study of the nucleic acids of the cotton plant, in which the relative quantity of certain base components of the DNA molecule showed a high degree of specificity not only to individual species of the cotton plant genus but also between species from widely ranging plant families.

Currently reported work has demonstrated that two DNA components, cytosine and 5-methyl cytosine, vary significantly and in accordance with taxonomical grouping of related species within the cotton genus. Such correlations tend to corroborate the involvement of nucleic acids in the transmission of heriditary characters and to provide the leads for the further research necessary to the understanding of the specific roles of these substances in determining plant traits.

Cotton Ginning. -- Additional cleaning equipment in gins necessitated by increased mechanical harvesting, declining volumes in some areas, and rising costs of variable inputs have resulted in a sharp upward movement in average ginning costs and created an urgent need for reliable information designed to increase ginning efficiency. Our research indicates some definite possibilities for most ginners. Substantial savings in power cost may be realized by peaking individual air systems used for materials handling; by rearranging gin machinery to eliminate unnecessary fans, motors, and piping; and properly loading electric motors. In addition, more efficient use of labor could reduce ginning costs between 13 and 33 cents per bale. Results also indicated that under present marketing conditions, most ginners can profitably reclaim their gin motes.

Costs of ginning cotton at single-gin and two-gin cooperative plants compared. Findings of this study showed that costs at single-gin plants were from 13 cents to $1.07 lower per bale than at two-gin plants when volume per gin was equal. This was caused mostly by two-gin units hiring more skilled labor on a year-round basis. Costs at gins operating at or near capacity were about $10 a bale less than at those ginning relatively low volumes. Results of the study raised the question of whether costs could be lowered further by gins storing seed cotton in baskets and by other methods to reduce ginning costs.

**Commercial Scale Evaluation of Alumina Bleaching Process for Cottonseed Oil. A practical batch process for bleaching off-colored cottonseed oils with activated alumina has been developed through the pilot-plant stage. Even the most discolored oils can be upgraded considerably by removal not only of the red pigments but also--by including carbon in the alumina slurry--of the vestigial greens. Since hard-to-remove discoloration occurs in about 25% of domestic cottonseed oils, a solution to the problem is of major import to the industry. A major producer and processor of cottonseed oil has already conducted engineering cost analysis of the process and has scheduled plant-scale tests for the near future, using an economic alumina produced by a leading manufacturer. That the process also effectively achieves deodorization enhances its applicability in regaining the competitive position of cottonseed oil.**

SRRL Fiber Retriever Enthusiastically Accepted by the Cotton Textile Industry. The SRRL Fiber Retriever--a simple, inexpensive Department-developed device that increases a carding machine's efficiency in removing trash from cotton to be spun--is being widely utilized in the cotton textile industry. Released to industry in the spring of 1963, the device is now being manufactured by six companies and fifteen companies have applied for licenses to manufacture it. Over 2,000 units are estimated to be in use and sales are reported to be increasing rapidly. Industry reports that the Fiber Retriever is essential for high production carding; and high production carding is a must for the cotton industry to compete with synthetics processing.

The Fiber Retriever consists of a series of baffles that replace the cleaning knives normally used in cotton carding machines. It increases cleaning efficiency at the cleaning section of the card as much as 40 percent and overall cleaning efficiency of the card as much as 12 percent. High speed production has no adverse effect on the Retriever's performance. In addition to its efficient removal of trash, the device removes a high percentage of short fibers, decreases loss of spinnable fibers, and decreases damage to the fibers. As a result, there are improvements in yarn strength and uniformity. Through use of the device processing costs are lowered and maintenance requirements for the card are decreased.

Solution Found for Historic Problem of Strength Losses in Wash-Wear Finishing of Cotton. Loss of strength in wash-wear cottons--a serious problem ever since all-cotton wash-wear garments were introduced--has been cut to a minimum by a new technique of mercerization developed by Department researchers. It has been discovered that pretreating cotton yarn or fabric with a mercerizing solution of caustic soda, followed by stretching, results in fabric that retains most of its strength after wash-wear chemicals are applied. The pretreatment does not affect the quality of the wash-wear finish. The new finding reverses present theories of textile chemists that substantial losses in tearing and breaking strength are inevitable in cottons given any of the wash-wear finishes now in commercial use. Cotton fabrics woven from pretreated yarn retained up to 90 percent of their breaking strength and up to 100 percent of their tearing strength after they were given wash-wear treatments. When the fabric itself was pretreated, it retained 75 to 80 percent of its tearing and breaking strength after the wash-wear finish was applied. Several textile companies are evaluating the new discovery.

# I. FARM RESEARCH

## COTTON CULTURE, BREEDING AND GENETICS, DISEASES, AND VARIETAL EVALUATION

Crops Research Division, ARS

Problem. The survival of the cotton production industry of the United States is dependent on the solution of two closely related factors. These factors are: (1) the lowering of the cost of production and (2) how effectively cotton can compete with synthetic fibers, particularly rayon, in the textile market. Essentially, the problem consists of an unfavorable relationship between the cost of raw cotton and synthetic fiber which is rapidly leading to a steadily increasing percentage of the foreign and domestic textile production changing from cotton to the man-made fibers. The obvious approach to this serious problem, for one of the major segments of the agricultural industry, lies in production research to lower the cost of production. At the present time, the cost-price squeeze makes it uneconomic for the average grower to produce cotton below the current domestic price (30¢/lb.) of cotton. Extensive surveys have shown that it would be possible to lower the cost of production by as much as 11¢/lb. if all out research is conducted on diseases, genetics and breeding, physiological problems, quality, insects, weeds, and other production problems of cotton.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving geneticists, agronomists, pathologists, engineers, physicists, and other scientists engaged in basic and applied research in an effort to solve problems confronting the cotton producing industry. The ultimate objective is to lower the cost of production, increase efficiency, improve the fiber and spinning quality, and thus to make the crop more competitive with man-made fibers.

In addition to the work conducted at Beltsville, Maryland, cooperative work is conducted with State Experiment Stations at Raleigh, North Carolina; Florence, South Carolina; Experiment and Griffin, Georgia; Auburn, Alabama; Stoneville and State College, Mississippi; Knoxville, Tennessee; Fayetteville and Marianna, Arkansas; Stillwater, Oklahoma; College Station, Lubbock, and Ysleta, Texas; University Park, New Mexico; Tempe, Arizona; and Davis, Shafter, and Brawley, California. Work is cooperative with the University of Missouri but no federal personnel are located there. Cooperative research is conducted with the Entomology Research Division at State College, Mississippi, and Brownsville, Texas; and with the Soil and Water Conservation Research Division at Brawley, California. Joint research work is conducted with the Southern Utilization Research and Development Division and with the Agricultural Engineering Research Division.

Cotton research is being conducted under two P.L. 480 contracts. One in India is on the biochemical genetic studies of plant pathogens, particularly to study parasexual recombination of filametous fungi. The second in Israel is concerned with genetic studies on the inheritance of characters influencing lint yield and quality in cotton using diallel cross analyses.

Under Memoranda of Understanding or Cooperative Agreements, cooperative work on contributed funds is conducted at Shafter, California, with the California Planting Cotton Seed Distributors and Kern County. At Tempe, Arizona, cooperative work is conducted on contributed funds from the Arizona Cotton Planting Seed Distributors. At Shafter, California, and Stoneville, Mississippi, the National Cottonseed Products Association contributes to cottonseed research. The National Cotton Council of America contributes to research at Iguala, Mexico; Davis and Shafter, California; and Beltsville, Maryland. The Federal scientific effort devoted to research in this area totals 71.1 professional man years. This number includes 18.0 devoted to physiology and culture; 25.6 to breeding and genetics; 13.5 to pathology; and 14.0 to quality.

## PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in plant breeding and genetics, plant pathology, plant physiology, agronomy, and fiber technology. In many of the States, the research is conducted cooperatively with the Department.

The Southern States are engaged in the development of breeding stocks to fit the particular needs of local environment. Both upland and long staple types are receiving attention. Major breeding emphasis is on fiber properties, particularly length, strength, and uniformity. Types are being bred for greater resistance to Verticillium wilt, Fusarium wilt, seedling diseases, nematodes, and blight. Much attention is being given to characteristics to aid mechanical harvesting such as earlier more uniform maturity, smaller plant size, and boll type. Some attention is being given to breeding methodology and attempts are being made to transfer characteristics from related Gossypium species into cultivated cottons. Most of the genetic work to support cotton breeding is being done within the regional project (S-1), Genetics and Cytology of Cotton, which is very effective in keeping this work coordinated. The Cotton and Cordage Fibers Research Branch participates very actively in this project. Attention is being given to the preserving and cataloging of genetic stocks and propagating them when necessary. Interspecific hybrids are made and followed with cytological and inheritance studies to determine the relationship of species. Other cytogenetic work concerns aneuploids, trisomics, chromosome deficiencies, and chromosome duplications and a larger objective of obtaining a complete set of monosomic lines for cotton. The inheritance of individual traits of cotton are being studied by both qualitative and quantitative techniques.

In cultural practices, the factors that limit yield are being studied as well as the effects of various practices on plant morphology, insect and disease reactions, fiber properties, and weed control. Other factors being studied are the use of winter legumes in cotton rotation, fertilizer levels, and rapid tests for determining the germination of cotton seed.

Fiber samples from the breeding and cultural experiments are submitted to State or Federal laboratories for evaluation of fiber and spinning properties. In Tennessee, special attention is given to devising new and better tests and improving equipment for measuring properties now considered standard in fiber testing. Some work is being done to establish end product serviceability relationships to specific fiber properties.

Cotton diseases are receiving the attention of scientists through research projects at several of the State Stations. In some cases, primary emphasis is being given to work on boll rots. New findings in this research, such as those on the role of Myrothecium roridum and B. subtilis, and the biochemical specifics of their mode of action, will contribute much to control of such diseases. Some boll rot diseases are being studied in relation to foliage exudates, other foliage characteristics, and fungi and bacteria associated with seed. Bacterial diseases of cotton and particularly X. malvacearum is receiving attention in a number of fundamental studies. The use of antibiotic resistant forms for study of genetic potential, biochemical basis for resistance, and enzymatic specificity in relation to virulence in Xanthomonas and in Pseudomonas pathogens offers much promise.

Fundamental work on the physiology of the Verticillium is in progress at four locations. Leadership in this research has resulted in new findings on metabolic pathways, absence of normal terminal oxidase systems, interrelation of virus and this fungus, biochemistry of toxin production, and mechanisms of resistance.

A number of Station scientists are concerned with an array of fungi, bacteria, and nematodes associated with seedling diseases and stand failures in cotton. Many of these organisms are being studied in sufficient detail such as to provide new knowledge which will be essential to development of effective controls. Phymatotrichum omnivorum is receiving special attention in three research projects to determine its physiology of parasitism and the biochemical specifics of resistance. Chemicals for control of nematodes, fungi, and bacteria are also being studied.

The total research effort on cotton is approximately 73.5 professional man-years, of which 2.7 is for culture, 46.2 for breeding and genetics, 15.6 for diseases, and 9.0 for variety evaluation.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Culture.

1. Flower Initiation and Maturation. Studies of the role of the environment in the initiation and maturation of cotton flowers have been continued during the past year. Preliminary evidence suggesting the interaction of the nutrient elements, nitrogen and phosphorous in the flowering response has been further investigated. Present evidence indicates that their role is at most an indirect one. The variable response to night temperature, observed with certain varieties, has been studied further in terms of the effect of genetic variation, germination environment, day temperature, and radiation intensity. Although some of these parameters have altered the observed flowering response, no direct relation to the observed variability in response to night temperatures has been indicated. These investigations point out the complexity of the floral induction process in the cotton plant and emphasize the need for continued effort to determine the environmental components responsible.

2. Biochemical Mechanisms in Genetics. Continued studies of the cytosine/5-methylcytosine (C/5MC) ratios as a species specific characteristic of deoxyribonucleic acids (DNA) of the cotton plant have provided further evidence relating C/5MC ratios to definite cytotaxonomic groupings. It was previously reported that cytosine or guanine/5 methylcytosine ratios of the DNA's of 13 species of cotton were correlated with the recognized cotton genomes. DNA isolated from seeds of G. tomentosum, a wild tetraploid from Hawaii, also coincides with the ratios obtained for the other tetraploids, G. hirsutum and G. barbadense. Further, the C/5MC ratios of two doubled haploids of G. hirsutum, designated DH-1 and DH-2, fit the previously published data on two other G. hirsutum doubled haploids. Thus, evidence continues to accumulate that species specificity within DNA resides within the guanine, cytosine, 5-methylcytosine portion of the DNA molecular structure of the cotton plant.

Previously, the nucleotide composition of entire-cell ribonucleic acid (RNA) was, on the other hand, reported to vary insignificantly from species to species. The nucleotide composition of RNA from roots and cotyledons has now been fractionated into particulate components and their nucleotide composition studied. The subcellular fractions obtained were as follows: (1) nuclei, (2) chloroplasts, (3) mitochondria, (4) microsomes, (5) soluble, and (6) cell wall. The nucleotide compositions of the various fractions have been investigated. The RNA composition of cotyledon and root isolates was found to be similar to each other and to that of entire cells. Soluble RNA, however, differed by having a higher cytidylic-adenylic acid ratio and a greater pseudouridylic acid content in both root and cotyledon isolates. Six nucleotides, in addition to adenylic, cytidylic, guanylic, pseudouridylic, and uridylic, were found in the soluble RNA fraction. Their chemical composition and significance are not presently known.

These results support the conclusion that total RNA at the subcellular level does not differ greatly from total cellular RNA in nucleotide composition. Continued research is necessary to fully evaluate compositional differences and similarities.

3. Mechanism of Abscission. Investigations of chemical nature of abscisin II, an abscission accelerating substance from young cotton fruit, and its physiological characteristics have been undertaken this past year. Physical and chemical determinations showed that abscisin II has a melting point of 160-161° C and sublimes at 120° C. It is an acidic, colorless compound, soluble in aqueous sodium bicarbonate, chloroform, acetone, ethyl acetate, diethyl ether, methanol, and ethanol. It is slightly soluble in benzene and in water but only sparingly so in petroleum ether. The ultraviolet absorption maximum in methanol is 252 mu (E 25,200). Its infrared absorption spectrum in KBr pellets and its nuclear magnetic resonance spectrum were also determined. The molecular weight of abscisin II is 264 (determined from mass spectrometry) and it contains 68.76% carbon and 7.96% hydrogen. Tests for nitrogen, sulfur, and halogens were negative. A tentative chemical structure has been assigned and work on the chemical synthesis of this structure has been initiated.

Chemical synthesis, from commercially available starting chemicals, has been postulated to require approximately 14 major reactions. Some have been accomplished with little difficulty. However, other reactions have presented serious problems, e.g., a highly unstable intermediate resulted from one attempted reaction and in another reaction, the desired end-product rapidly polymerized. Considerable progress has, however, been made towards the successful synthesis of this compound.

Physiological characterizations of abscisin II obtained from the sample purified from the previously reported young fruit extraction has established:

(a) Abscisin II induces considerably more rapid abscission than either gibberellin or auxin.

(b) It accelerates abscission when applied, either proximal or distal to the abscission zone.

(c) It strongly retards auxin-induced growth in a standard auxin bioassay.

(d) It has no gibberellin activity (dwarf corn mutant bioassay).

A comparison of the abscission accelerating activity extractable from young fruit of varying ages (2 to 50 days) has been initiated. So far, it is clear that abscisin II activity is abundant until at least the eighth day of fruit development and is absent from fruit 40 to 50 days old. Work is progressing on the intervening ages.

At least two gibberellins have been found in young cotton fruit. Research to adapt assay methods for the identification of gibberellins in cotton is in progress.

Recently an abscission retarding substance was detected in extracts of young fruit.

4. Harvest-aid Chemicals and Procedures. Technological improvements in production, harvesting, and ginning procedures appear to have altered somewhat the position of harvest-aid chemicals in harvesting practices. Comparisons in the far west of the effect of defoliants and desiccants on the crop with that from fields not treated with harvest-aid chemicals have yielded the following information:

(a) Highest yields of lint were obtained where no harvest-aid chemical was applied.

(b) Defoliant application reduced yield, coarseness, maturity, and micronaire of skip-row cotton and coarseness, maturity, and micronaire of solid plantings.

(c) Desiccant applications reduced micronaire values of skip-row cotton and coarseness of solid plantings but did not affect yields. Lack of effect on yields is attributable to the later time of application possible with desiccant-type chemicals. Further evaluations are needed to adequately assess the trends suggested by these findings.

Losses from boll rots have continued to increase and interest continues in bottom defoliation (removing leaves from the lower part of the plant by directed defoliant sprays) as a preventative measure. The principal hazard is too early leaf removal or the removal of too great a proportion of leaves resulting in reduced yields and/or seed and lint quality.

Timing and placement studies conducted in the far west suggest that early applications (August 29) permitted compensation for bolls lost as a result of treatment, whereas, applications at the usual time (September 20) delayed maturity and increased the possibility of occasional yield losses. Similar studies in the mid-south show treatment effects on fiber and seed maturity as measured by seed index, oil content, and micronaire.

Attempts to alter plant shape and size by mechanical lateral and top pruning throughout the season to permit a more favorable environment for opening bolls, to reduce lodging, and to produce a plant more suitable for mechanical harvesting has yielded the following information: (a) Yields were reduced 27% by topping and 21% by vertical trimming. (b) No clear-cut evidence of impaired fiber and seed maturity was obtained.

Evaluations of experimental defoliant and desiccant chemicals have been continued. Although several materials show promise, their efficacy ranges with that of currently available commercial chemicals.

5. Germination, Emergency, and Early Seedling Growth. The establishment of adequate stands of cotton and the growth of the seedling during the early part of the growing season when periods of low temperature and adverse weather conditions are likely to occur remain a serious problem in cotton production. In addition, the ability to culture immature embryos and an understanding of the physiological and biochemical requirements for embryo maturity are useful tools to the geneticist and physiologist alike.

The reaction of immature embryos to nutrient composition and environmental influences has been further explored. The calcium salts of malic, citric, and succinic acids in appropriate concentrations increased growth rate. Incorporation of these acids was suggested by analyses of the composition of liquid endosperm from seeds containing young cotton embryos. The sugars detected were sucrose, fructose, and glucose. Malic acid in concentrations as high as 5 gm per liter and lower concentrations of glutamine, asparagine, and several amino acids were observed.

Investigations undertaken to characterize and study the physiology of germinating cotton seeds and emerging seedlings have yielded evidence to support the concept that low temperature injury to the seedling from the beginning of germination is additive and persistent. The physiological nature of this response is currently under investigation. Metabolic studies of the effect of low temperature on emerging seedlings have yielded the following tentative conclusions which require further verification and testing:

(a) Hydrolysis of storage proteins and lipids contained in cotyledons (storage organs) continues at low temperatures, although rates are somewhat reduced.

(b) The end products of hydrolysis (amino acids and simple sugars) accumulated in the cotyledon, probably due to interrupted transport mechanisms.

(c) Emerging seedlings are not dependent on an external source of mineral nutrients.

Chilling of established young cotton plants also resulted in increased concentrations of simple sugars, amino acids, and soluble protein. To test the effect of the increased concentrations noted above on growth and proliferation of seedling disease organisms, stems of chilled and nonchilled seedlings were homogenized in water and the sterilized supernatant used as the sole substrate for culture of the seedling disease organism Rhizopus solani. Growth of the organism was almost twice as great on the culture

from chilled plants. Investigations are continuing on the relationship between incidence of seedling diseases and the plant constituents which accumulate as a result of chilling.

Further clarification of the efficacy of a hard-seed character in preserving seed quality was obtained in 1962. Evidence was also obtained that methods other than hot water treatment may be useful in breaking the dormancy of hard seed. Techniques have been developed for screening large quantities of seed for this trait and utilization of these methods have resulted in the isolation of plants from commercial varieties with the hard seed character.

6. Plant Responses to Insects and Insecticides. The hazard of indiscriminate use of agricultural chemicals and the necessity for careful evaluation of potential interactions have been demonstrated this past year in research showing increased injury to cotton plants by applications of combinations of the phosphate insecticides, Di-syston and phorate with the preemergent herbicides, monuron and diuron. That such interactions are not characteristic of all phosphate insecticides was demonstrated when a combination of Bidrin and monuron showed no apparent interaction.

7. Plant Response to the Environment. In California, continued research on the factors affecting plant response to skip-row plantings confirm the yield advantages previously reported. South exposure rows out-yield north exposure. Differences between adjacent rows are least when they run in a north-south direction. Yields tend to increase with increase in width of skips up to 200 inches (4 rows). These data implicate lateral root growth as one of the limiting factors in the yield response.

Eighteen professional man-years are devoted to physiology research.

B. Breeding.

1. National Cotton Variety Testing Program. Results from the five Upland regional programs and the extra-long staple (Pima) regional test from the 1962 crop were published in ARS 34-60. Approximately 1,000 copies of this report were distributed to interested individuals and to agricultural libraries. Field performance and fiber and spinning data from the 1963 crop are being analyzed for publication. The systematic collection and analysis of data have been useful in estimating the yield and range of adaptability of varieties. The results show that fiber and spinning properties are influenced less by environment than yield and that six distinct fiber types based upon fiber and spinning data account for the inherent differences among most American varieties.

2. Cotton Winter Breeding Facility, Iguala, Mexico. During the 1963-64 season, some 40 individuals representing federal, state, and private breeders had about 15 acres of cotton grown in Mexico during the winter. Requests for crosses, self-pollinations, and other services were performed as usual. The species garden was expanded to supply seed for

biochemical studies of the seeds. The principal value of the Iguala facility is to accelerate research by making possible two generations per year.

3. Release of Seed Stocks. The Oklahoma Agricultural Experiment Station, U. S. Department of Agriculture cooperating, released two varieties of cotton in March 1964. Verden was developed from blight resistant selections from the Northern Star Variety, and Kemp was developed from blight resistant selection of crosses of Stoneville 20 and Stoneville 62. Early maturity, the open type boll, and improved fiber strength over current varieties grown in the area are characteristics of both varieties.

The New Mexico Agricultural Experiment Station, U. S. Department of Agriculture cooperating, released Acala 1517V in the spring of 1964. Acala 1517V is intended for planting in the Texas-New Mexico area commonly referred to as the El Paso Trade Territory. The new variety maintains the high standards of fiber quality long established as characteristic of the area and offers increased resistance to verticillium wilt, more storm tolerance, and a higher lint percentage than Acala 1517D.

4. Breeding for Special Characters.

(a) Glandless (gossypol-free) cottonseed. Public and private breeders of all major cotton varieties are attempting to develop glandless cottons equal to or superior to current commercial varieties. The performance of glandless strains in yield trials has ranged from excellent to below average. Breeders have no evidence that glandless is inherently associated with any deleterious character with the possible exception of insect susceptibility. There is evidence that certain insects prefer glandless to glanded when given a choice. Field, greenhouse, cage, and laboratory experiments were designed to further investigate the relation of glandless characters on insect preference.

At a conference on Cottonseed Protein Concentrates in New Orleans in January, it was emphasized that glandless seed, which are essentially free of gossypol and other objectional pigments, would be of great benefit to the cottonseed crushing industry. It would make cottonseed a much more useful oilseed and would offer an important new source for human food, particularly in areas of the world where proteins are in short supply.

(b) Smooth leaf and nectariless. Cooperative research with the Entomology Research Division has shown that smooth leaf and nectariless are individually beneficial in reducing development of lepidopterous insects and that the effect is accumulative when both are bred into a single strain. Additional tests of these characters with regard to insects were planned and one strain with these traits was placed in several 1964 yield trials. Smooth leaf has also been established as a desirable trait for producing cleaner cotton.

(c) Hard seed coat. Hard seed is a common characteristic of Gossypium species and many primitive uncultivated stocks. It has been shown that cottonseed with an inherently impermeable seed coat can withstand adverse weather conditions in the fall and maintain a higher germination percentage and better milling quality than permeable seed. A soaking treatment followed by freezing technique has been worked out and thousands of seed of cotton varieties were screened for this trait. A few hard seed were found in five cotton varieties and some of them transmit the character to their progeny. The impermeable condition can be broken prior to planting with a hot water treatment. The inheritance of the character is not known precisely and an inheritance study was begun.

5. Extra-long Staple Breeding. The 1963 season was excellent for yields of Pima cotton. Test data indicate that Pima S-2 yielded on the average over 25% more than Pima S-1 with individual tests ranging from 1% less to 77% more for Pima S-2. Fiber length was shorter in 1963 than in previous years and some bales fell below the 1-3/8" required for qualification under the support price which created a marketing problem. The shorter staple is probably a combination of environmental, harvesting, and ginning influences, but a major objective of the breeding program is to increase the inherent length of Pima so that environmental variations will not place any significant number of bales below 1-3/8".

The Pima program has an extensive breeding effort where new germ plasm, hybrids, and selections are made and tested in Arizona, New Mexico, and Texas. The major objectives, in addition to staple length, are improved yields, earlier maturity, adaptability to machine harvesting, and greater adaptability to the wide range of environmental conditions encountered from Yuma, Arizona, to Pecos, Texas.

Supporting the breeding and testing program is a basic genetics and cytological program discussed under the paragraph on basic studies.

6. Insect Resistance. Host plant resistance research has shown that substances extracted from the cotton plant vitally influence the behavior of the boll weevil. These substances influence the feeding, oviposition, fecundity, rate of development, and vigor of the insect. About 60 stocks of cotton were screened for the arrestant and feeding stimulant substance using square extracts incorporated into agar plugs. About 20 lines were sufficiently low to warrant more intensive study. Square samples from over 250 additional stocks from the germ plasm collection were collected for assay for weevil resistant properties. A laboratory method for testing antibiosis properties of cotton by rearing weevils on a diet prepared from reconstituted, lyophilized square powder was developed. One hundred and seventy-seven stocks were evaluated and 18 demonstrated enough antibiosis to merit further study. A method was developed for measuring the rate of oviposition and 275 lines were tested, 26 of which merit further study.

7. Germ Plasm Collection in National Seed Storage Laboratory, Ft. Collins, Colorado. Fundamental to the success of any long range crop improvement program is the collection and preservation of the germ plasm of the species. Prior to the establishment of the National Seed Storage Laboratory, cotton germ plasm was kept at Stoneville, Mississippi; College Station, Texas; and Tempe, Arizona, under a plan coordinated by Regional Project S-1. As of January 1964, fresh self-pollinated seed of 1,302 stocks had been deposited in Ft. Collins. These stocks represent the species of Gossypium, the primitive noncultivated cotton of the tropics, old agricultural varieties, current agricultural varieties, genetic markers, and unique breeding stocks. Noncultivated stocks have in the past been the source for varietal improvement and several potentially important traits (bacterial blight resistance, glandless, nectariless, smooth leaf, male-steriles, fiber strength, hard seed, insect resistance, nematode resistance) have been derived from this source.

8. Basic Cotton Genetic Studies. Research experience has demonstrated that basic studies on the genetics and cytology of a species ultimately contribute to the improvement of the cultivated forms of the species. The basic work of the USDA and several states is coordinated through Regional Research Project S-1. Results of the work have been summarized in a 20-page document, and only a few highlights are reported here.

Ten new monosomics (plants lacking one chromosome) and additional translocations (plants with chromatin or heredity material structurally rearranged) were identified. This advances the work to develop a series of lines in which all 26 chromosomes will be cytologically marked. Half the chromosomes are now marked and are being employed to locate specific genes, establish linkage relationships, evaluate influence of specific chromosomes, and to substitute chromosomes from one species into another.

Inheritance studies and linkage relationships of several mutant characters were completed. These results are cumulative over years and contribute to the mapping of the known genes on specific chromosomes.

A new species, G. barbosanum from the Cape Verde Islands, was described and found to be closely related cytologically to two African species.

It has been shown that irradiating pollen with gamma rays can induce changes from the dominant to recessive condition in known genetic markers. Irradiating pollen of plants marked with recessive traits did produce certain dominant expressions which could be due to mutation or possibly deletion of bits of chromatin. Irradiation of pollen of commercial varieties induces mutations and certain of these were studied genetically.

Cytological studies to determine the relationship among cotton chromosomes from different species were continued.

Research on heterosis and combining ability showed that certain $F_1$ hybrids yield 15-20% more than commercial varieties. Tests of diverse stocks exposed to high levels of natural crossing indicated that this tends to boost yield. Under PL 480 project in Israel, it was learned from a diallel experiment involving four hirsutum and four barbadense varieties that interspecific hybrids, intraspecific hirsutum hybrids, and intraspecific barbadense hybrids yielded 82, 38, and 25% more than the mean of the parents, respectively. No feasible way to produce $F_1$ seeds in quantity seems likely, but attempts to exploit partial hybrids will continue.

9. Long Range Breeding Objectives. Most cotton breeding objectives require a minimum of 10-15 generation of crossing or selection work followed by three or more years of performance testing. New and difficult objectives may take longer. Annually, there may not appear much change even though progress is being made. In this category are the efforts to combine high fiber and spinning quality with other agronomic attributes for Delta and Southeastern cottons; incorporation of disease resistant genes into breeding stocks and varieties; development of varieties with storm resistant bolls particularly adaptable for spindle-machine picking; development of stormproof boll for stripper harvest in certain areas of Arkansas and the Delta; and studies to evaluate the response of cotton varieties to climatic factors and management practices.

The Federal scientific effort devoted to research in genetics and breeding totals 25.6 professional man-years.

C. Diseases

1. Bacterial Blight. By using the new series of differentials which have been set up by the bacterial blight committee of the Cotton Disease Council, the various races of the blight organism which occur in the United States can be distinguished. Research has shown that the selections carrying resistance to the angular leaf spot and black arm phase of the disease do not necessarily carry resistance to the boll rot phase. Inasmuch as the boll rot phase of this disease is causing increased yield losses as well as losses in fiber quality, an intensified effort is under way to determine which of the resistance genes or combination of genes will impart resistance to the boll rot phase. Resistance to the angular leaf spot and black arm phases of the disease, caused by the blight races which occur in the United States, is now available in the form of breeding stocks or released varieties. With an intensified effort on determining the genetics of resistance to the boll rot phase, it is hoped that within the near future breeding stocks will be available to Federal, State, and private breeders to be used in developing resistant adapted varieties. The blight eradication program in California has apparently been successful since no damage was reported in 1963. Longevity of the pathogen in dried plant material and its significance in dissemination of the disease have been worked out. Other work in progress is concerned with determination of the role of common antigens in the host and parasite to resistance of the host to the disease. Also work

is in progress on antigens in the parasite as they relate to host specificity.

2. Fusarium Wilt. The continued use of fusarium wilt resistant varieties, particularly in the southeastern states, is reducing the production hazard from this disease. Certain of the fusarium resistant varieties have resistance to race 1 of the blight organism incorporated which enhances their value for production in the rain grown areas of the cotton belt. The screening service provided under this program in Alabama, where more than 2,000 plots of breeding material are evaluated each year, is continuing to raise the general level of fusarium resistance in the commonly used varieties. The program of incorporating nematode resistance into fusarium resistant varieties continues to progress and breeding stocks are now available which carry this combination of resistance factors.

3. Verticillium Wilt. In spite of efforts by the cotton breeders and pathologists to minimize the losses from this production hazard, the disease continues to spread into new areas each year. In the highly productive San Joaquin Valley of California, it has been found that Verticillium in combination with Thielaviopsis, and perhaps other associated microflora, is causing an unusual disease syndrome which has rendered formerly tolerant varieties almost completely susceptible. A greatly expanded and intensified effort to assess the role of each of the factors involved in this disease syndrome is now under way. Basic research on the nature of resistance to Verticillium continues to give encouraging results. Xylem fluid collected from susceptible and tolerant varieties has produced differential reactions on germination and development of conidia of the fungus. Analyses of the xylem fluid have shown the presence of at least 7 sugars and approximately 14 amino acids. Maltose is the only sugar that appears to be highly stimulatory, and of the amino acids only aspartic acid, asparagine, and glutamic acid appear to be of importance. It is hoped that this research will provide a working tool for the plant breeders in developing resistance. The micro-biological approach to control of Verticillium wilt has been interrupted by the loss of a staff member but it is hoped that this approach can be continued at the earliest possible time.

4. Disease Nematode Complexes. Research has shown that several genera of nematodes predispose cotton seedlings to disease. Also certain species of nematodes predispose fusarium resistant varieties to fusarium wilt in areas where the nematodes occur in abundance. Soil fumigation and treating the seed with a nematocide have increased the chances of obtaining and maintaining a stand of healthy plants. New screening techniques developed under this program make it possible to select from a segregating population those individuals which carry the highest degree of fusarium resistance which also imparts nematode tolerance. Research under this program has also shown that certain species of nematodes are associated with specific diseases while others do not contribute materially to the disease syndrome.

5. Seedling Diseases of Cotton Including Cold Tolerance. Obtaining and maintaining a uniform stand of vigorous plants is one of the greatest

uncertainties facing the cotton producer today. Research has shown that the use of soil fungicides to supplement seed treatment is an economically feasible aid in obtaining and maintaining a stand from the first planting. The "hopper box" method of applying soil fungicides where the material is applied to the seed before planting has proved to be the most economically and widely accepted method of applying soil fungicides. It is estimated that more than one and one-half million acres are treated in this manner annually. Continued progress is being made on the selection of lines of cotton which are able to produce essentially normal growth increments in seedlings at temperatures which were formerly thought to be below that for seedling growth. The increased vigor of the cold tolerant seedlings appears to impart a certain degree of seedling disease resistance. Certain selections have produced normal seedlings at temperatures below that usually considered minimum.

6. Boll Rots. Because of the emphasis on increased acre yields with resulting overgrown plants from the increased fertilizers and water used, the boll rot situation has continued to increase each year. Basic studies in Mississippi on microclimate effect on boll rot and fungicidal control have shown that through the use of fungicides and bottom defoliation, an economical and profitable degree of control can be obtained. Basic studies in California are under way on the boll constituents and the influence of these constituents on the incidence and severity of boll rot, also the influence of environment, moisture, and fertility levels on the amounts of the various constituents found in the bolls. Further studies are oriented toward an explanation of the role of these factors individually and in combination on boll constituents and on boll rot. These studies, it is hoped, will be helpful in suggesting cultural practices which possibly may minimize losses from this production hazard.

7. P.L. 480 Research. The work has only been initiated with no progress to report.

There are 13.5 professional man-years assigned to cotton pathology problems.

D. Quality and Varietal Evaluation.

1. Automation of Cotton Fiber and Spinning Tests. All data obtained from the 50-gram spinning tests at Knoxville are now automatically recorded on IBM punch cards. This includes data on skein strength as well as on fibrograph length and micronaire values that are used in setting the spinning equipment rolls. These data are analyzed by computer and print-outs of data are sent to the various field locations which have submitted materials for testing.

Work is now under way to make it possible to record all data from the fiber laboratory automatically on punch cards.

2. Stress-Strain Studies. Intensive studies on stress-strain relationships of cotton fiber bundles on the Instron were made on five varieties

(with extremes of Acala 1517 and Lankart 57) grown at six locations in the western states. Those studies were undertaken to obtain a better understanding of the relationship between values obtained in routine testing on the stelometer and values determined with the Instron.

Studies have shown that when the finishing drawing sliver is tested with the Pressley jaws at a gauge length presumed to be 1/8", the actual "true gauge length" is not 3.175 cms. but found to be approximately 3.55 cms.

A striking correlation (r=.997) was found between $T_o$ value on the stelometer and Young's modulus corrected to the true gauge length.

The relation of these values to the X-ray diffraction pattern (40% angle) is also being studied.

3. Organisms that Decompose Cellulose. Basic studies to determine which micro-organisms can and which cannot decompose cellulose as it exists in a cotton fiber have continued. Recent research has focused particularly on the behavior of certain organisms generally considered to be "non-cellulose-decomposers" or "weak cellulose decomposers". Data now show that Aspergillus niger can weaken cotton if the medium is somewhat acid, that Pythium spp. and Rhizopus spp. can weaken swollen but not unswollen cotton fibers. The behavior of wood-rotting fungi, which have failed in experiments to date to weaken cotton fibers, is still being examined. No certain proof has been found in the literature that any actinomycete can weaken a cotton fiber; after failure with several isolates, an active isolate has been found.

4. Fragmentation of Cotton Fibers. In a basic study of enzyme action in relation to cotton fibers and their structure, an entirely new type of quantitative assay for the enzyme cellulase has been developed. Cotton fiber which is shaken vigorously for two hours in suitable enzyme-containing solution, fragments into short pieces and the resultant fragmentation is measured by a suitable filtration-weighing technique. The new assay is of interest to research workers on cellulase because it employs an unaltered cotton fiber as a substrate, in contrast to the usual highly modified celluloses used in most other assays. The fiber-fragmenting cellulase is produced during growth on cellulose by Fusarium moniliforme, Rhizoctonia solani, Cladosporium herbarum, and Sclerotium rolfsii. Action is obviously highly localized in the fiber, since complete fragmentation of the fiber into very short pieces may occur with only about 1% loss in fiber weight. Like other cellulases produced in the same manner, the fragmenting cellulase exhibits high resistance to degradation by heat and drying. A highly variable ratio of fragmenting activity to increases in alkali-swelling and to action on carboxymethyl cellulose ("CMC-ase") adds further evidence to a now rather widespread belief that "cellulase" consists of a mixture of several related but functionally different enzymes.

5. Improved Fiber and Spinning Properties. This phase of the work is conducted jointly with the Genetics and Breeding Investigations. Efforts to

develop more strength and more length in commercial varieties have led to the conclusion that above a certain threshold of fiber properties, yield and length and yield and strength are inversely correlated. Below this threshold value, selections for strength (or length) appear to be independent of yield. The threshold value is not constant but in turn varies with the climate. Thus it is possible with present germ plasm to obtain better combinations of yield and strength in the San Joaquin Valley in California than it is in the Mississippi Delta. The question of whether it is possible to change this threshold by altering the germ plasm has led to extensive breeding efforts to develop improved fiber qualities, particularly in the southeastern United States and mid-south.

These breeding efforts have been made chiefly with stocks that have introgression of germ plasm from other cotton species, as well as from the stock known as "Hopi Acala".

There has been a gradual rise in the yield of selections having superior strength in recent years and 1963 tests would indicate that this trend continues. In 1964 for the first time, a regional "high strength" strain test has been inaugurated at 9 locations in 8 states in the southeast and mid-south with entries from 7 breeders.

Fourteen professional man-years are devoted to research in quality and varietal investigations.

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## CORDAGE FIBERS CULTURE, BREEDING AND GENETICS, DISEASES, AND VARIETAL EVALUATION
Crops Research Division, ARS

Problem. Almost all of the leaf and stem fibers used in the United States are imported from the Orient, Brazil, and East Africa. The production of most of these fibers in the United States is dependent upon mechanization, the development of high yielding disease resistant and cold tolerant varieties that are suitable for mechanized handling, and upon improved methods of retting kenaf and jute. Some progress has been made in mechanization. More information is needed on cultural requirements that affect fiber quality and yield. Additional information is needed on breeding behavior of Hibiscus sp. in order to transfer disease resistance from one species into another. The control of root-knot nematodes through crop rotation and fumigation needs further study. Sansevieria hybrids more cold tolerant than parental material have been developed; however, more information on factors affecting cold tolerance is needed in order to broaden the area where the crop could be grown. Recently, considerable progress has been made by spinning mills in the use of decorticated kenaf fiber, the use of which would enhance the possibilities of domestic production, however, the use of such fiber has been accompanied with "gum buildup" on spinning equipment. More work needs to be done with batching methods to eliminate gums prior to spinning.

### USDA AND COOPERATIVE PROGRAM

The Department's program with cordage fibers involves genetics, breeding, culture, diseases, and varietal evaluation.

The work is cooperative with the University of Florida, Everglades Experiment Station, and the Agricultural Engineering Research Division at Belle Glade, Florida. Kenaf varietal testing at Tifton, Georgia; Experiment, Georgia; Knoxville, Tennessee; and Lafayette, Indiana, has been cooperative with the respective experiment stations.

Industry conducted research in Alabama concerning the production and processing of kenaf for pulp. Some chemical companies supply chemicals for testing in the control of root-knot nematodes.

The federal scientific effort devoted to research in this area totals 3.5 professional man-years. This number includes 1.0 devoted to breeding and genetics; 1.0 to pathology; .5 to quality and varietal evaluations; and 1.0 to culture.

### PROGRAM OF STATE EXPERIMENT STATION

The major effort by any State in this area is support for a cooperative program with the Department in Florida on ramie, sansevieria and kenaf. The objective is breeding for higher yield and resistance to disease and nematodes. Fertilizer rates and cultural practices are also being studied.

Several states are determining the adaption of stem and leaf fiber crops as part of new crops projects.

To a limited degree research is in progress at the state stations on the diseases of plants having potential as a source of cordage fibers. Some of the effort in these investigations is directed toward establishing ecological relationships. Other studies are designed to develop techniques for the isolation of disease resistant plants which could be used in breeding programs. Two of the more destructive fungi-causing diseases of these crops are species of Collectotrichum and Fusarium. Nematodes have also been indicted as disease agents and research will make possible effective control in many of these crops, such as ramie, kenaf, roselle, sansevieria, the agaves, hemp, and abaca.

The total research effort on cordage fiber is approximately 1.6 professional man-years.

## PROGRESS - USDA AND COOPERATIVE PROGRAMS

### A. Breeding and Genetics

1. Kenaf. Root-knot nematodes continue to be the most serious pest limiting the growth of kenaf, Hibiscus cannabinus. Hibiscus acetosella possesses good resistance; however, crossing with kenaf resulted in sterile hybrids. Subsequently, successful crosses were made between H. radiatus and H. acetosella and between H. radiatus and H. cannabinus. H. radiatus was then used as a bridging species to transfer nematode resistance from H. acetosella into H. cannabinus. The (H. radiatus-acetosella-cannabinus) cross resulted in one fertile seed per 12 capsules which compared favorably with the H. radiatus x cannabinus cross; 1 seed per 7 capsules. However, backcrossing of the progenies to H. cannabinus resulted in a drastic reduction of fertility.

The following new hybrids combinations were obtained: H. radiatus x H. meeusei, H. furcellatus x H. sabdariffa, H. acetosella x H. sabdariffa meeusei, H. aculeatus x H. furcellatus, and H. bifurcatus x H. aculeatus. Two hybrids resulting from spontaneous amphidiploidy, H. radiatus-diversifolus $F_2$ and H. sabdariffa-meeusei $F_2$ were grown in 1963.

Cytological analysis established that H. sabdariffa has no genomes in common with H. cannabinus or with H. furcellatus, H. bifurcatus, and H. aculeatus. H. meeusei has one genome in common with H. sabdariffa and with H. cannabinus.

One professional man-year is devoted to breeding and genetics.

### B. Diseases

1. Kenaf. A Phytophthora species was identified as one of the fungi contributing to the nematode disease problems in Florida and Georgia.

Results of a study to determine the specific influence of certain crops on the population of several Pythium species indicates a definite relationship between crop and abundance of a particular Pythium. The production of rye on soil that had been inoculated with equal proportions of Pythium irregulare, P. spendens, P. ultimum, and P. mamillatum resulted in P. ultimum increasing to 88% with a simultaneous reduction of P. irregulare to near zero. The production of kenaf on soil inoculated with the same proportion of Pythium species resulted in a sharp reduction of P. ultimum. This may lead to a practical method of controlling Pythium. Botrytis attacked kenaf, hemp, roselle (H. sabdariffa) and several vegetable crops. The fungus attacking tomatoes and peppers appears to be the same as that attacking kenaf, roselle, and hemp.

The severity of two soil-borne diseases incited by Sclerotium rolfsii and and a species of Rhizoctonia was increased by the use of DD soil fumigant.

2. Sansevieria. No new diseases were observed on sansevieria; however, an abnormally high population of sheath nematodes was associated with unthrifty plants of Florida H-13.

One professional man-year is devoted to disease investigations.

C. Quality and Varietal Evaluation

1. Kenaf. Kenaf variety trials were conducted at Tifton, Georgia; Knoxville, Tennessee; and Experiment, Georgia. Highest yields were 1495 pounds of fiber per acre at Experiment, Georgia. The varieties Everglades 41 and 71 were superior in yield to all others included in the test.

A kenaf strain trial was grown on Everglades peat soil and included Everglades 41 as a check, 61 late maturing lines selected from diallel cross progeny, and 2 late maturing lines from other parentage. When harvested 122 days after planting, the check yielded 4100 pounds of fiber per acre, while the best late line, BG-61-42, yielded only 2580 pounds of fiber per acre.

A kenaf-roselle strain trial was planted on root-knot nematode infested soil for the third consecutive year. The nematode resistant roselle line A59-56, which was obtained from Pakistan, yielded 1530 pounds of fiber per acre, and the highest yielding kenaf, Everglades 71, yielded 1250 pounds of fiber per acre. Fiber quality research involving studies on strength and fineness was continued at Belle Glade, Florida.

One-half professional man-year is devoted to quality and varietal evaluation.

2. Fiber Plants Not Produced Commercially in the United States. Planting material of outstanding varieties of abaca is being maintained in Florida. Sisal plants were selected from vigorous clones for use in cultural studies.

D. Culture.

1. Kenaf. Kenaf seed yields on mineral soil were not affected by pH in a range of 4.3 to 7.5.

A late maturing kenaf variety, BG-58-10 produced 615 pounds of seed per acre, while the standard varieties Everglades 41 and Everglades 71 produced 360 and 310 pounds per acre, respectively.

A row spacing experiment was designed for kenaf on mineral soil and included 7", 14", 21", 7" skip row 7", 14", 21" skip row 21". The 7"-14"-7" resulted in highly significant greater seed yields than all other spacings.

2. Sansevieria. In an age of harvest study on Everglades peat soil, the sansevieria hybrid Florida H-13 was harvested at 18 months, 24 month regrowth, and 48 month regrowth, with the following respective yields in pounds of fiber per acre per year: 1430, 2040, and 2520. This demonstrates the advisability of delaying harvest, which is now possible because of the cold tolerance of the hybrid which has survived 5 winter seasons at Belle Glade, Florida.

In fertility trials with sansevieria on mineral soil, the use of inorganic sources of nitrogen resulted in a significantly greater fiber yield (2800 pounds per acre) over organic sources, the use of which resulted in only 1500 pounds of fiber per acre. Higher yields were obtained when the nitrogen was applied once a year in March, rather than twice a year in March and September.

An experiment was designed to determine the effect of 4 sources, 3 rates, and 2 times of application of potash on yield of sansevieria on mineral soil. When nitrogen was held constant, yield was not affected by source, rate, or time of application of potash, with the exception of nitrate of soda-potash. When an increase of nitrogen was accompanied by an increase of 200# of $K_2O$ to 400# of $K_2O$, yields increased from 2900 to 4300 pounds of fiber per acre, respectively. Highest yield was 5600 pounds of fiber per acre which resulted from the application of 400# of $K_2O$ and 450# of nitrogen per acre, and applied three times a year.

3. Ramie. Superior clones were increased. Denier counts were made on fiber from high yielding clones and on material produced by several degumming methods.

One and one-half professional man-years were devoted to cultural investigations.

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## WEED AND NEMATODE CONTROL
Crops Research Div., ARS

Problem. The control of weeds is the most critical economic problem in many phases of agriculture. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. The national annual loss in agricultural production due to weeds has been estimated to be about 2.5 billion dollars. The losses caused by weeds must be reduced by expanding research to find more effective methods of weed control. Improved weed control methods will facilitate farm mechanization, greatly increase production efficiency of the use of human and land resources in agriculture. Research on the life cycles of weeds is critically needed so that any weaknesses in the reproduction, spread, and survival characteristics of weed species can be expolited in developing methods for their control.

Plant-parasitic nematodes occur in all soils used for growing of crops and plants and attack all kinds of plants grown for food, forage, fiber, feed, or ornamental purposes. Damage is partly due to the direct effect of the nematodes feeding on the roots or other parts of the plant, and partly due to invasion of nenatode-damaged tissue by bacteria, or fungi. Nematodes have been found to be vectors of several plant viruses. Economic damage to crop plants by nematodes varies greatly from field to field, but data obtained from experimental plots commonly demonstrate crop yield reductions of 25% and reductions in excess of 50% are often found. Nematodes can be controlled by crop rotations, cultural practices, chemicals and biological agents, and damage can be avoided by growing nematode resistant crop varieties. All of these control methods involve a certain amount of expense and none are as efficient as desired. There is urgent need for fundamental research on the taxonomy, physiology, ecology, and relationships of nematodes to bacteria, fungi and viruses.

### USDA PROGRAM

Much of the weed control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry and certain private groups. The work is cross commodity in nature. The weed control program involves a total of 58 professional man-years. Of this total 6.4 is specifically directed to weed control in cotton. The program is being conducted in Beltsville Maryland; Raleigh, North Carolina; Stoneville, Mississippi; Temple and Mesa, Arizona; and Shafter, California.

The Federal scientific effort devoted to basic and applied nematode research is 19 professional man-years, of which 1.7 is devoted to applied research in cotton at Auburn, Alabama; Temple, Arizona; Tifton, Georgia; Baton Route, Louisiana; and Weslaco, Texas.

## PROGRAM OF STATE EXPERIMENT STATIONS

All the State experiment stations are conducting basic and applied research in weed control. These studies involve evaluation of selective herbicidal properties of new chemicals to show the relation between chemical structure, herbicidal activity and weed-crop selectivity; the nature, behavior, and effect of herbicides on their degradation products in and on plants and plant products; the mechanism of herbicidal action; influence of climate, plant morphology and soil characteristics on the effectiveness of herbicides in selectively controlling weeds and on their persistence in plant tissue. Studies are being conducted on the movement and persistence of herbicides in various soil types and the phenomena involved in absorption and other interaction of herbicides with clay complexes.

Nematode investigations are being conducted at most of the State Stations and many of these scientists participate in the four Regional Research Projects concerned with phytonematology. Through these and other projects at the various institutions scientists are contributing new knowledge on the genetics, physiology, and pathology of nemas. Some station scientists, as a result of their recent findings on nemas as vectors of viruses, are conducting intensive investigations of the biologies of this process. Other research on fundamental problems in nematology as well as work on identification and control are indicated in the appropriate crop section of this report.

The total research effort on Nematode Identification, Physiology, and Control at the State Stations is approximately 52.2 professional man-years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

### A. Weed Investigations

#### 1. Cotton

a. Physiology, Biochemistry, and Ecology. At Raleigh, North Carolina, excised root tips and hypocotyls (or mesocotyls) of cotton, soybean, and corn exhibited similar patterns for uptake of two herbicides. Uptake of simazine was predominantly nonmetabolic, whereas that of 2,4-D required expenditure of metabolic energy.

At Raleigh, North Carolina, no evidence was found for active metabolism of prometryne in cotton. Trace amounts of the 2-hydroxy analog were detected in soil-grown plants only. The moderate tolerance of cotton to prometryne appears to result from binding or complexing of the chemical at non-sensitive sites.

b. Weed Control. Greenhouse and field evaluations of 30 new herbicides for weed control in cotton at Stoneville, Mississippi, demonstrated considerable promise for 2 herbicides, 2-cyano-4-ethylamino-6-isopropylamino-s-triazine and swep, as preemergence treatments. Five new s-triazine and urea herbicides field-tested for postemergence activity were relatively inactive against drought-stressed grass. Two applications of 3 lb/A of DSMA plus surfactant provided better control of drought-stressed grass than 0.4 lb/A of diuron or prometryne plus surfactant. In secondary evaluations, trifluralin, norea, and prometryne applied before or at planting by surface and subsurface placement methods gave good preemergence control of annual grass without adverse effects on cotton yield. In California and Arizona, R-4461 appeared promising as a postemergence herbicide.

Evaluation of several recommended postemergence herbicides continued at Stoneville, Mississippi. Cotton tolerance to diuron, prometryne and DSMA in directed sprays increased after plants were taller than 3 inches. Plants 6 inches tall were highly tolerant. No residues occurred in cottonseed following use of these herbicides as directed postemergence sprays. Cotton was not as tolerant to topical applications of prometryne and diuron, and some mid and late season topical applications of DSMA resulted in detectable residues of arsenic in cottonseed. In preemergence treatments, the addition of a supplemental subsurface, split-band treatment with EPTC to the recommended triband weed control practice provided better control of annual weeds and nutsedge and reduced costs and labor requirements without affecting yields. Combinations of herbicides with cultivation appeared more effective than single component practices.

In California, Arizona, and Mississippi, various preplant, preemergence, and postemergence treatments with DSMA, DCPA, DCMA, trifluralin, diuron, linuron, and prometryne with and without surfactant provided good control of broadleaved weeds, annual grasses, and Johnsongrass from seed. Diuron plus surfactant gave consistently good control of emerged weeds at all three locations. Either DSMA or diuron was effective against Johnsongrass from seed but not from rhizomes. Trifluralin as a preplant soil-incorporated treatment gave excellent weed control but was more effective in irrigated cotton when applied and incorporated prior to preplanting irrigation. Diuron applied pre- and postemergence was superior to prometryne for weed control in cotton grown without cultivation in Mississippi. Trifluralin and DCPA were more effective than diuron in layby applications in irrigated cotton.

B. Nematode Control

1. Cotton. A new nematocide phenyl,N,N-dimethylphosphorodiamidate (sold as Nellite by the Dow Chemical Company) tested to determine its effect on cotton production at Tempe, Arizona, gave inconclusive results. In greenhouse experiments designed to measure the use of water by cotton infected

by root-knot nematodes (Meloidogyne incognita acrita), and uninfected cotton at Tempe, Arizona, it was found that where an abundance of water was always supplied, both infected and uninfected plants grew normally. But where water supply was intermittently limited, simulating field conditions, top growth of the uninfected plants were 5-1/2 times as great as that of the infected plants. That is, the uninfected plants grew normally, but the infected ones were badly stunted.

Field experiments at Baton Rouge, Louisiana, demonstrated that the reniform nematode, Rotylenchulus reniformis, can reduce cotton yields as much as 32 percent, but that is easily controlled by standard nematocides. A species of the genus Hemicycliophora (as yet undescribed) has been found to be a new nematode parasite of cotton in Alabama. It is an ectoparasite feeding on root tips, and suppression of lateral root development is the principal pathological symptom.

At Auburn, Alabama, Fusarium wilt of cotton occurred only in pots inoculated with both root-knot nematodes (Meloidogyne incognita acrita) and Fusarium wilt, nearly all of the plants showing wilt symptoms 24 days after planting, while none of the plants in pots inoculated with nematodes alone or Fusarium alone had wilt symptoms. Reduction in growth of tops was only slight in pots inoculated with nematodes alone, and there was no top growth reduction in pots inoculated with Fusarium alone, but where the two were combined, average growth was reduced about 50 percent. Similar effects were produced by a combination of sting nematodes (Belonolaimus longicaudatus) and Fusarium.

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## COTTON INSECTS

### Entomology Research Division, ARS

Problem. Insects are major deterrents to economical production of cotton and their control is a major cost factor in the production of the crop. Although many highly effective insecticides have been made available, the development of resistance to certain insecticides in 20 cotton insect pests emphasizes the need for basic information on ways to solve or avoid the problem and to develop other methods of control that are more effective, economical and desirable. There are some hazards involved in the use of current insecticides because of possible resulting residues in food and feed products made from cottonseed and because of drift to vegetable and fruit crops, and to forage crops consumed by animals. An imbalance of beneficial insect populations and hazards to fish and wildlife may result from insecticides now employed on cotton. More research on approaches to control such as sterile male techniques, attractants, feeding stimulants, repellents, cotton varieties resistant to insects, biological control agents, safer insecticides, more effective ways of applying them, and chemically induced plant resistance to insect attack is needed to develop improved methods of control. Effective methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. The boll weevil is gradually extending its range westward and may be adapting itself to an arid climate. Infestations in northern Sonora, Mexico, could endanger cotton production in California where the pest does not now occur. One of the basic difficulties in cotton insect control is the lack of knowledge of factors influencing insect abundance. Such knowledge could serve as a basis for advising growers when control measures for the various pests will or will not be required.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long term program involving entomologists, insect and plant physiologists, insect pathologists, insect and plant geneticists, chemists, biochemists, agricultural engineers, soil scientists, and economists engaged in basic studies and the application of known principles to the solution of cotton growers' insect problems. Studies of ecological factors affecting abundance and distribution of cotton insects are conducted at Tucson, Ariz., Tallulah, La., State College and Stoneville, Miss., Florence, S. C., and Brownsville and Waco, Tex., in cooperation with the Agricultural Experiment Stations in the respective States and with ARS Plant Pest Control Division. Fundamental research in determining physiological processes and biochemical requirements in the normal metabolism of the boll weevil, bollworm, pink bollworm and cabbage looper is conducted at Baton Rouge, La., State College, Miss., Florence, S. C., College Station and Brownsville, Tex., in cooperation with the Agricultural Experiment Stations in the respective States. Studies of mode of action and fate of various chemicals in the insect, mechanisms by which insects develop resistance to

insecticides, and how such mechanisms may be rendered ineffective are conducted at Baton Rouge, La. in cooperation with the Louisiana Agricultural Experiment Station. Evaluations of candidate chemicals for cotton insect control in the laboratory and field are conducted at Tucson and Tempe, Ariz., Tallulah, La., State College and Stoneville, Miss., Florence, S. C., and Brownsville, College Station, and Waco, Tex., in cooperation with the respective Agricultural Experiment Stations and Industry. Development of safe, economical and effective schedules of insecticide applications for guidance of growers in meeting the wide variety of insect problems on cotton is underway at Tempe, Ariz., Tallulah, La., Stoneville, Miss., Florence, S. C., and Brownsville and Waco, Tex., in cooperation with the respective Agricultural Experiment Stations. Studies involving insect pathogens for control of the boll weevil, bollworm, tobacco budworm, and cabbage looper, and beneficial insects for the control of several cotton insects, are conducted at Brownsville and Waco, Tex., Tucson, Ariz., State College and Stoneville, Miss. and Florence, S. C. in cooperation with the Agricultural Experiment Stations in these States. Research to discover new approaches to control cotton insects such as sterile male techniques, attractants, feeding stimulants, and repellents are conducted at Tallulah, La., State College and Stoneville, Miss., Florence, S. C., Brownsville, and College Station, Tex., in cooperation with the Agricultural Experiment Stations in these States. Studies to evaluate equipment for insect control and detection such as stalk shredders, machines to collect and destroy boll weevil infested cotton squares, gin and oil mill equipment, and light traps, are conducted at State College and Stoneville, Miss., and Brownsville and Waco, Tex., in cooperation with the Agricultural Experiment Stations in these States and with the Agricultural Engineering Research and Plant Pest Control Divisions. Varietal evaluation for insect resistance is studied at Tucson, Ariz., State College, Miss., and Brownsville, Tex. in cooperation with the Agricultural Experiment Stations in these States and the Crop Research Division.

The Federal scientific effort devoted to cotton insects research totals 64 professional man years. Of this number 22.1 are devoted to basic biology, physiology and nutrition; 17 to insecticidal and cultural control; 5.2 to biological control; 11.7 to insect sterility, attractants and other new approaches to control; 1.3 to evaluation of equipment for detection and control; 3.7 to varietal evaluation for insect resistance; and 3 to program leadership.

## PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research programs on cotton insects are conducted by the major cotton-producing States. Information is being obtained on the ecological factors responsible for rapid population increases of pest insects as a basis for accurate forecasting of destructive outbreaks. Variations in insect numbers and behavior through hibernation, spring emergence, summer development and diapause are being determined. Laboratory studies are underway to learn what factors are responsible for initiation of diapause

in the boll weevil, pink bollworm and bollworm. Emphasis is being placed on the influence of light, nutrition and temperature. Other studies are concerned with the influence of chemosterilants and radiation on reproductive physiology. Laboratory rearing techniques, using artificial lights, are being developed to provide insects for year-round study, and to determine the effects of varying concentrations of nutrients in the diet.

Biological information is being assembled on rates and characterization of developmental stages, rate of egg deposition, mating habits, longevity and mortality.

Cultural control studies include the influence of varying fertilizer levels on infestation size, the benefits obtained from crop residue destruction in the fall, and the development of varietal resistance. Research in the last area consists of screening introduced plants for resistance, crossing them and selecting progeny which exhibit useful traits. Biological, physiological and chemical studies are conducted to determine the factors responsible for resistance.

Chemical control studies include the evaluation of new materials with particular emphasis on systemic insecticides. Research includes basic mode of action studies in insects and the metabolism of systemic insecticides in the cotton plant. Various methods of application are being evaluated for field use.

The total State scientific effort devoted to cotton insect research is 21.5 man-years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition.

1. Boll Weevil. Heavy boll weevil infestations were present in cultivated cotton in Sonora, Mexico, in the summer of 1963. In a field near Oquitoa 46% of the squares were punctured on July 25. The infestation had increased to 77% on August 29 even though the field had been treated twice with Guthion. Forty percent of the squares were punctured in a field near Magdelena on August 27 and 37% in a field near La Salina on September 13. Percentages of squares infested in cotton fields near Caborca, Desemboque, and La Salina, were 100, 79, and 90, respectively, on October 17 and 18. Similar infestations were found in the area last year.

First thurberia weevil punctured squares were found on cultivated cotton in southwestern Arizona on August 21 in 1963. Nine thousand three hundred squares were inspected in 16 fields in the upper Santa Cruz Valley. Punctured squares were found in 14 fields but only about one percent of the squares were punctured.During November light to moderately heavy infestations of boll weevils were observed in eastern Yuma, southeastern Pinal, and

various parts of Pima Counties. The heaviest infestation was located about 5 miles south of Stanfield in Pinal County.

Boll weevil survival in the spring of 1964 was higher than in 1963 in all areas except Texas and 3 areas of the Carolinas. Spring woods-trash examinations for hibernating boll weevils were made in central Texas, northeast Louisiana, Delta and Hill sections of Mississippi, and in four areas in the Carolinas. Comparative survival since 1960 in the various areas was as follows:

| | Weevils per acre | | | | |
|---|---|---|---|---|---|
| Area | 1960 | 1961 | 1962 | 1963 | 1964 |
| Central Texas | 2065 | 1516 | 1361 | 452 | 97 |
| Northeast Louisiana | 4754 | 2193 | 2233 | 121 | 1049 |
| Mississippi | 821 | 1246 | 1132 | 13 | 289 |
| South Central, S. C. | 861 | 376 | 1667 | 914 | 753 |
| Coastal Plains S. C. & N. C. | 1049 | 1129 | 3654 | 1560 | 2742 |
| Piedmont S. C. & N. C. | 590 | 1558 | 2833 | 350 | 134 |
| North Central, N. C. | 377 | 430 | 968 | 161 | 107 |

Survival was lower in all areas of the Carolinas except in the Coastal Plains. Survival was lower in central Texas than in any year since such records have been made. Although survival in Louisiana and Mississippi was greater than in 1963, it was considerably lower than in previous years.

The ground trash survey by Tucson, Ariz. laboratory personnel in April 1964 in Sonora, Mexico, showed averages of 138 and 360 boll weevils per acre in treated and untreated fields, respectively. Treated fields received 3 biweekly airplane applications of methyl parathion beginning in early October, 1963.

No weevils were found overwintering in ground trash in Arizona by Tucson laboratory personnel. Ground trash inspections from 17 fields in Pima, Pinal, Santa Cruz and Yuma Counties made in February, and April, 1964, indicated that the thurberia weevil in Arizona had not been able to adapt itself to survive the winter in ground trash. Field-collected adults placed in hibernation cages containing ground trash at two locations where infestations occurred last year, also, failed to survive.

Overwintering boll weevils at a rate of 1100 per acre were found in last year's cotton bolls on April 13 in a Pinal County stub cotton field by Tucson, Arizona, laboratory personnel. In such fields the plants are cut at ground level and the new crop is produced from the previous year's root stocks. Adult weevils were recovered from terminal growth on stub cotton as early as April 21. Fourteen weevils were collected on April 15 from a hibernation cage containing 200 bolls from the same field.

The boll weevil infestation in squares increased ten-fold between June 1 and 22 in an Arizona stub cotton field. Tucson laboratory personnel found 50 weevil-punctured squares per acre on June 1, 640 on June 15, and 5,009 on June 22, in a stub cotton field in Pinal County. Second generation adults were emerging by June 11.

In laboratory studies at Tucson when the $F_1$ generation resulting from crossing weevils from wild cotton, Gossypium thurberi, with weevils from domestic cotton was back crossed to the parental lines, progeny from all crosses reproduced, indicating that the weevils are of the same species.

Preliminary results at State College, Miss. indicate development of an easy method of marking large numbers of boll weevils for field studies. Yellow model lacquer, diluted 1:1 with acetone, was applied to boll weevil adults with an atomizer. At the end of three weeks the markings were very conspicuous and mortality was insignificant.

Three additional species of Cienfuegosia and one of Thespesia were hosts of the boll weevil at Brownsville, Tex. Susceptibility of Cienfuegosia differed among six species grown in the nursery, three of which were previously reported hosts. In general, the species not found in areas inhabited by the boll weevil were the least susceptible.

In studies at Baton Rouge, La. aseptically and non-aseptically reared adult boll weevils were equally capable of synthesizing long-chain fatty acids from acetate. Palmitic, palmitoleic, stearic, oleic, and linolenic acids were the principal ones synthesized. The studies further indicated that the boll weevil cannot synthesize linoleic acid from acetate, and cannot convert dietary linolenic acid to linoleic acid.

Gas chromatography of isolated sterol esters of diapausing adult boll weevils at Baton Rouge, La. revealed that oleic acid is the principal acid esterified with sterols. Paper chromatography of the esters indicated that they were at least 97% pure and were not contaminated with glycerides or glyceride fatty acids. The sterol ester fraction also gave a very strong positive test for sterol.

In studies at Baton Rouge, La. the sugar content of cotton bolls was five to eight times greater than in squares. This differential probably explains why glycogen and triglyceride levels are higher in boll-fed than in square-fed weevils. Preliminary results indicate that the major sugars in bolls and squares are glucose, fructose, and perhaps sucrose.

Triglyceride need in the diet for normal development and reproduction in the boll weevil was determined at Baton Rouge, La. Larvae of normal appearance and size were obtained from essentially fat-free diets. The only deficiency symptom was a slightly retarded growth rate. Progeny from parents reared and fed with fat-deficient diets developed normally on fat-deficient larval diet. Resistant and non-resistant strains of weevils developed equally well on diets without fat. Surprisingly, weevils from the two strains required

just as much endrin to produce a given mortality as when reared from diets with the usual amount of fat.

In studies at College Station, Tex., sublethal dosages of systemic insecticides reduced egg production of boll weevils. Adult boll weevils maintained under constant systemic insecticide pressure by being fed the toxicant or by allowing the weevils to walk on treated filter paper, produced few or no eggs. Feeding was much more effective in reducing egg production than the residue treatment. One ppm of phorate, Bidrin, American Cyanamid 47470 or 47031 in artificial diets almost stopped egg production.

Use of $C^{14}$-labeled acetate in studies at Baton Rouge, La. indicated that the boll weevil has an active mechanism for the biosynthesis of lipids. Radioactivity from injected $C^{14}$ appeared in neutral lipids and phospholipids. The weevil incorporated 2.8% of the labeled acetate into the lipid fraction within 2 hours of injection. About 1.8% was recovered as $C^{14}O_2$ from respiratory oxidation of the acetate molecule. Fatty acids appeared to be the principal compounds synthesized by boll weevils from the $C^{14}$ acetate precursor. Approximately 90% of the recovered radioactivity was in the saponifiable fraction. Ten percent was not saponifiable. A small portion (about 17%) of the non-saponifiable fraction was precipitated by digitonin, indicating the possibility of sterol biosynthesis in this insect.

Boll weevils reared on high cholesterol diets at Baton Rouge, La. tolerated about 1.5 times more methyl parathion than those reared on diets containing the usual amounts of sterols. Tolerance levels were not increased when the weevils were reared on diets containing increased amounts of selected amino acids, triglycerides, or a mixture of cholesterol and cholestanol. The purpose of the test was to determine whether it would be feasible to increase the tolerance of sterilized insects to insecticides by nutritional means before their release in the field.

Radiotracer studies at Baton Rouge, La. showed that almost all of the cholesterol in newly emerged adult boll weevils was replaced within 15 days. This high rate of sterol turnover had been indicated by earlier nutritional studies. Significant amounts of $C^{14}$-cholesterol were esterified and smaller amounts were converted to more polar steroids. Fat weevils contained more sterol esters than lean weevils. The polar steroid fraction recovered from adult feces was separated into several components by means of thin layer chromatography.

Catalytic hydrogenation of crude body fat of the boll weevil at Baton Rouge confirmed earlier identifications of the unsaturated fatty acids, and revealed traces of two additional minor components. Gas chromatography of hydrogenated fat showed a trace of $C_{19}$ fatty acid that was obscured by the large polyunsaturated $C_{18}$ peaks. Also, a small peak in the $C_{17}$ area which disappeared after hydrogenation is probably palmitolenic acid. It represents less than 1% of the crude mixture.

In studies at Baton Rouge the hydrocarbon and sterol ester fractions of boll weevil lipids were isolated by thin layer chromatography using two different solvent systems in series. A preliminary development in petroleum ether moves the hydrocarbon fraction almost with the solvent front and leaves the sterol esters near the origin. A second development in petroleum ether, ethyl ether and acetic acid (84:15:1; v/v/v) to a point 3 cm below the first front and then resolves the sterol esters. Three distinct sterol ester spots have been isolated from crude body fat by this method.

The composition of purified boll weevil larval glycogen was determined in studies at Baton Rouge, La. The glycogen is 66.3±0.8% carbohydrate positive material, 5.8±0.5% protein, 10.4±0.5% moisture, and 7.7% ash. Chromatography on Sephadex G-200 and high voltage paper electrophoresis did not show any carbohydrate contaminant.

A method was developed at Florence, S. C., for accurate sex determination of boll weevils. Weevils are anesthetized with $CO_2$. Each specimen is held between the index finger and thumb with the posterio-ventral portion of the insect facing the observer so that the morphology of the last tergum and sternum is exposed. The weevil is illuminated with a bright light and viewed through a stereoscopic microscope with a magnification of approximately 25 diameters. The seventh tergum of the female is wider (1.1 mm.) than long (0.5 mm.) and fits smoothly against the edge of the last sternum. The eight tergum of the male is narrower (0.5 mm.) and shorter (0.3 mm.) than the seventh tergum of the female. The distinguishing characteristic of the male is a notch in the ventral portion of the eighth tergum.

In studies at Florence, S. C., the boll weevil was most sensitive to light in the 500 to 510 mu region (green) of the spectrum. Electroretinograms of the compound eye of laboratory-reared weevils indicated that the greatest sensitivity occurs in the 500 to 510 mu region of the spectrum. Cotton foliage reflects light in this range.

Studies of the systemic activity of Shell SD-9129 in the cotton plant and its metabolism in insects, rats and the cotton plant at College Station, Tex., showed that SD-9129 is not translocated when applied as a foliar treatment but is readily translocated when applied as a stem treatment. It undergoes oxidation in insects and rats similar to the closely related compound, Bidrin. In all animal species studied, hydrolytic degradation apparently occurred only at the methyl-phosphate and vinyl-phosphate bonds of the molecule. No amidase action was detected.

Radioassay and biological assays were used in systemic activity studies of Di-Syston at College Station, Tex. Di-Syston applied 12 inches under the soil surface was absorbed more readily by plants 18 inches tall than when it was placed 6 inches deep. The ability of the plant to take up the toxicant depended on the dispersal of the toxicant in the soil. The application of Di-Syston to cotton stems was not very effective. $P^{32}$-labeled material was used in studies of metabolism of Di-Syston in cotton insects and

the cotton plant. A total of five oxidative and ten hydrolytic metabolites were found.

The substitution of sucrose for glucose improved the amino acid diet for boll weevils in nutrition studies at College Station, Tex. Substituting 3.5 g. of sucrose for 2.5 g. of glucose and increasing glutamic acid from 125 mg. to 325 mg. per 100 g. of diet improved the boll weevil amino acid diet. Several other sugars were tested. Sucrose, fructose, and maltose gave the best results. Lactose, corn starch, cellibiose, glucose, and mannose were intermediate and galactose, melibiose, and ribose gave poor results.

The percentage of fatty acid fractions varied with boll weevils' susceptibility to various insecticides in studies at Florence, S. C. The percentage of stearic acid was higher and the percentage of palmitic and oleic acids was lower in insecticide-susceptible boll weevils than in those resistant to the insecticides. Three strains of weevils reared on different artificial diets and field-collected weevils were treated with Guthion, carbaryl, toxaphene, and toxaphene plus DDT. The survivors and dead from all treatments showed this difference in fatty acid content.

In studies at Florence, S. C. three strains of laboratory-reared weevils were most susceptible to toxaphene when fed a diet containing soybean lecithin and least susceptible when fed cotton squares. Weevils surviving treatment with Guthion, carbaryl and toxaphene plus DDT were generally heavier and contained a higher percentage of lipid than the dead ones.

Length of photoperiod that will initiate diapause in the boll weevil has been determined in studies at Baton Rouge, La. Periods of fluorescent illumination less than 11 hours and 40 minutes tended to enhance diapause induction. Longer photoperiods suppressed diapause. This information will be useful in future studies of the photoperiodic action of light of different wavelengths.

In studies at Stoneville, Miss., boll weevil adults required 2 to 3 weeks to attain firm diapause under controlled environmental conditions in the laboratory. When larvae were reared on artificial diets, squares, or bolls under an 11-hour photoperiod at 80° F., and when adults were fed on squares or bolls under continuous light at 80° F. In other experiments larvae were reared on squares, bolls, or artificial diets under continuous light at 80° F. Adults from these larvae fed on squares and bolls under continuous light at 80° F., or held under a 12-hour photoperiod at 80° F. in the day and 50° F. at night fed squares or bolls required a similar period to attain firm diapause.

In nutrition studies at Baton Rouge, La. cholestanol did not satisfy the sterol requirements for boll weevil development but it reduced the need for cholesterol in the diet. Larvae did not develop normally when reared on diets containing less than 20 mg. of cholesterol per 100 g. of diet. However, they were able to develop satisfactorily on diets containing only 10 mg. of

cholesterol supplemented with 10 mg. of cholestanol. Larvae did not survive on diets containing 100 mg. of cholestanol alone.

$C^{14}$-labeled fatty acids from the boll weevil were separated and identified by gas chromatography at Baton Rouge, La. Radioassay of the separated esters was accomplished by collecting them on silicone-coated anthracene crystals in glass cartridges. The cartridges were then counted for $C^{14}$ in a scintillation spectrometer.

Effects of several amino acid analogs on boll weevil development were studied at College Station, Tex. DL-Methionine and allylglycine appeared to be detrimental to its development.

Sub-lethal treatment of boll weevils with toxaphene increased egg production in tests at State College, Miss. Female weevils that survived treatments with toxaphene laid more eggs than untreated females. However, approximately 50% of the treated females died by the fourth day after treatment.

The metabolism of Di-Syston by adult boll weevils and bollworm larvae was compared in studies at College Station, Tex. Fifth-instar bollworm larvae absorbed and excreted the toxicant very rapidly following topical treatment. After 72 hours, 78% of the applied dose was excreted. Adult boll weevils also absorbed and excreted Di-Syston quite rapidly. Bollworm larvae rapidly oxidized and then hydrolyzed injected Di-Syston. Ingested Di-Syston was oxidized to a lesser extent but was rapidly hydrolyzed in the gut. The metabolism of Di-Syston by adult boll weevils was similar to that of bollworms except that no Di-Syston sulfone was recovered from the weevils.

In studies at Baton Rouge, La. boll weevils reared on larval diets containing a minimum amount of sterol and deprived of any sterol during the adult stage, laid practically no eggs and survived only a short time. The mean life span for adult weevils on diets essentially free of sterols was 14 days as compared with 55 to 89 days for square-fed weevils. It made little difference whether the weevils were or were not mated. Such a dependence on dietary sterols has not been observed in any other insect. The addition of cholestanol to cholesterol-free adult diets increased egg production and prolonged the life span probably by supplementing or sparing the cholesterol carried over from the immature stages.

Glycogen levels through the life cycle of the boll weevil were determined in studies at Baton Rouge, La. Eggs contained the largest quantity of glycogen (about 11% of the dry weight) and the late last instar larvae were second (about 6%). During the pupal period, glycogen content gradually decreased and reached a minimum in the one day old adult. Diet has a profound influence on the rate of glycogen accumulation. Glycogen increased slowly in the square fed weevil and reached a peak at the fifteenth day. When the weevils were fed bolls, however, glycogen content increased very rapidly--from about two micrograms in the one-day old adult to about 70 micrograms in the two day old weevil. This sudden increase was probably caused by a high titer of glucose in the boll.

Chemoreceptor and mechanoreceptor sense cell response was recorded from the boll weevil in electrophysiological studies at Florence, S. C. In preliminary electrophysiological technique studies of the boll weevil, satisfactory mechanoreceptor recordings have been made from the antenna and chemoreceptor recordings from the sensilla basiconica on the maxillary palps.

In studies at State College, Miss. clear, mitotic metaphase figures have been observed in the thurberia weevil and the chromosome number has been established to be 44 as in the boll weevil. However, small differences between thurberia and boll weevil chromosome configuration have been observed.

2. Pink bollworm. A low mating frequency of pink bollworms was indicated in early-season populations in studies at Brownsville, Tex. Laboratory studies showed that each spermatophore represents one mating. Dissections of females collected in light traps over a 2-year period showed a high percentage to be unmated early in the season and during the noncotton season when the population density was low. As the population increased with advance of the growing season, the proportion of mated individuals showed a significant correlation to numbers trapped in the respective trapping periods, as did the mean number of matings per female. Of the total trapped during the study a majority mated only once. Laboratory studies of caged populations showed that females have the potential to mate an average of 4.3 times (range, 0-10) and males 2.3 times (range, 0-8). Among these caged populations, 5% of the males and 3% of the females failed to mate, and 10% of the once mated females contained no spermatophores when dissected.

Winter survival of pink bollworms was reduced by low temperature and high soil moisture in bio-climatic cabinet studies at Brownsville, Tex. A cabinet simulating winter temperatures at Heavener, Okla., resulted in a survival 1/10 of that in a cabinet simulating the higher winter temperature at Waco, Tex. Under Waco temperatures a soil moisture of 16% significantly reduced survival from that obtained at a soil moisture of 8%. No difference in survival due to soil moisture was found under the lower temperatures at Heavener, Okla.

3. Other Cotton Insects. Surveys by Brownsville, Tex. personnel of cultivated hosts in the lower Rio Grande Valley of Texas during July, August and September showed that an increasing proportion of the larvae was Heliothis virescens. This species was not found on corn or grain sorghum. Attractive cultivated hosts during late August and early September were scarce. During this time a few H. zea were found on Passiflora suberosa. H. virescens was more abundant on this plant than H. zea and was also found in small numbers on sunflower.

Heliothis zea larvae in corn ears completed development after killing frost at Brownsville, Tex. Collection of bollworm larvae for experimental

purposes was interrupted by temperatures of 32° and 27° F on December 23 and 24, 1963. High populations of H. zea were observed in corn ears after these low temperatures. The larval mortality appeared to be low and collections after the freeze showed that a high percentage of this December-January brood completed development.

The effects of several amino acid analogs on bollworm development were studied at College Station, Tex. DL-Methionine and allylglycine appeared to be detrimental to its development.

Lygus bug injury did not appear to cause "flat square" problem on cotton in studies at Tucson, Ariz. Some individual cotton seedlings exposed to as many as five lygus bugs grew into deformed and somewhat stunted plants which produced fewer squares and blooms than did plants not injured by lygus feeding, but no flat squares resulted indicating that lygus bugs probably are not responsible for the flat squares produced by cotton plants in Arizona fields.

Tarnished plant bugs reduced cotton yields in cages at Stoneville, Miss. Studies of different adult populations released in replicated large screen cages indicated that adults migrating into cotton fields at a weekly rate of 1 to every 5 cotton plants can significantly reduce cotton yields.

Spanogonicus albofasciatus overwinters in egg stage on fall and winter weed hosts at Tucson, Ariz. In laboratory studies where green winter host material was brought into the laboratory and held long enough for incubation, S. albofasciatus nymphs hatched from Sisymbrium irie, Malva parviflora and Erodium cicutarium.

B. Insecticidal Control.

1. Boll Weevil. Six applications of 0.5 pound of methyl parathion per acre, plus defoliation, followed by 1.0 pound of Bidrin was the most effective boll weevil diapause control program tested at State College, Miss. The above combination of treatment procedures was highly effective in reducing boll weevil numbers during September and October. Good results also were obtained when 2.0 pounds of Bayer 41831 per acre was substituted for Bidrin in a similar program. The fields were replanted to cotton in 1964. On June 9 no weevils were found in two fields which had been defoliated or treated with Bidrin following methyl parathion treatment in the previous fall. However, weevils at the rate of 26 per acre were found in the field treated with Bayer 41831 after the methyl parathion treatments had been made.

Different volumes of spray in airplane applications of insecticides were equally effective in controlling cotton insects at Tallulah, La. Airplane applications of the same dosage of toxaphene plus DDT were made throughout the season in 1, 2, and 3 gallons of total liquid per acre application in comparison with Hi-Boy applications of 4 to 6 gallons per acre. There was no difference in insect control, fruiting of the cotton plant, or yield for the different volume rates of spray applied.

In field tests at Stoneville, Miss. under moderate to heavy late-season boll weevil infestations a mixture of Guthion plus Ethyl Guthion at 0.5 and 0.75 pound was as good or better than Guthion plus DDT at 0.25 plus 1.0 pound per acre. Under light to moderate boll weevil infestations Union Carbide 21149 at 0.25 pound, Stauffer N-2404 at 0.5 pound, American Cyanamid CL-47470 at 0.5 pound, and Guthion plus Ethyl Guthion at 0.25 pound per acre held the infestation below that of the check and were equal to or better than the standard.

In field cage tests at College Station, Tex., American Cyanamid compounds CL-47031, CL-47470, and E.I. 47772 applied as sprays at 0.25 pound per acre were as effective against boll weevils and spider mites as the same dosage of Guthion plus Ethyl Guthion.

In field cage tests against adult boll weevils at Waco, Tex., Imidan at 0.5 pound, Bayer 41831 at 1.0 pound, Guthion at 0.125 pound plus Ethyl Guthion at 0.125 pound, and Guthion at 0.25 pound per acre gave kills of 100%; Bayer 25141 at 0.5 pound, 95%; Monsanto CP-40294 at 0.5 pound, 90%; and Bidrin at 0.25 pound per acre, 89%.

In greenhouse tests at College Station, Tex., the boll weevil feeding stimulant used in conjunction with systemic insecticides apparently increased foliar feeding by adults enough to increase rate of kill about threefold over plants treated with only the insecticide.

2. Pink Bollworm. Twenty two candidate insecticides were tested for toxicity to pink bollworm adults in laboratory and field cage tests at Brownsville, Tex. Six were highly toxic to adults in the initial laboratory screening tests and two, Shell SD-8972 and SD-90201, retained appreciable toxicity after a 24-hour outdoor exposure of the spray residues. None was very promising in field cage tests. Populations were too low for the evaluation of insecticides against this pest under field conditions.

3. Other Insects. In field experiments at Waco, Tex., Shell SD-8447 at 1.0 pound and SD-7438 at 1.5 pound per acre gave bollworm control equal to that obtained with toxaphene at 2 pounds plus DDT at 1 pound

per acre. Shell SD-7438 and SD-8448, each at 1 pound per acre, were less effective. There was no significant difference in bollworm control obtained with 1.4 pounds dosages of DDT or TDE or in mixtures with toxaphene at 2.5 pounds plus DDT or TDE at 1.25 pound per acre.

In laboratory tests at Tucson, Ariz., Bayer 42696 and American Cyanamid 47548 at 2 pounds, and American Cyanamid 48938 and E.I. 38906 and Bayer 41831 at 1 pound per acre were effective against bollworms.

Stem treatment with systemic insecticides continued to show promise in tests at College Station, Tex. Preliminary tests with Bidrin, Shell SD-9129, and American Cyanamid CL 47031 as stem treatments showed that all of these materials were toxic to third-instar bollworms caged on leaves of treated plants. American Cyanamid CL 47031 continued to be the most effective stem treatment material for boll weevil control.

In small field cage tests at Florence, S. C., General Chemical GC-4702 at 1.5 pounds, carbaryl at 1.2 to 2 pounds, TDE at 2 pounds, DDT at 2 pounds, toxaphene plus DDT at 2 pounds plus 1 pound, and methyl parathion at 1 pound per acre, were effective against the bollworm.

In laboratory tests at Tucson, Ariz., Bayer compounds 41831, 37289, 38156, and 25141 were effective against beet armyworms at 0.5 pound per acre. American Cyanamid E.I. 38906, CL-47470 and E.I. 47772 and Bayer 37289 and 38156 were effective against cabbage loopers at 1 pound per acre. All of the above compounds were effective against the cotton leaf perforator at 0.5 pound per acre. American Cyanamid E.I. 38906, Bayer 41831 and 38156, Niagara N-9227, Geigy G-13005, Stauffer N-4446, R-5762 and R-5763 at 1 pound and Bayer 37289 and Shell SD-9129 at 0.5 pound per acre, were effective against salt-marsh caterpillars. All Bayer compounds and American Cyanamid compounds were effective against adult lygus bugs at 0.5 pound per acre. Shell SD-9129 was effective at 0.25 pound. At Waco, Tex., CL-47031 applied to cotton stems at 0.19 pound per acre and as side-dress granule application at 1.3 and 2.06 pounds per acre gave good reductions of a light cotton fleahopper infestation. In field tests, Union Carbide UC-21149 granules applied in the furrow at planting gave cotton fleahopper control for 7 weeks after cotton was planted. The first significant hatch of nymphs occurred between the 7th and 8th week after planting while in a similar phorate treatment at 1.2 pound, the hatch occurred between the 5th and 6th week. In the untreated check and in the phorate seed treatment at 0.2 pound it occurred one week earlier than in the latter treatments. On June 11, approximately 8 weeks after planting, the nymphal infestation was 16 per 100 terminal

buds in the UC-21149 treatment, 58 in the phorate seed treatment, 66 in the phorate granular treatment, and 83 in the check. There were significantly more squares and blooms on plants in the UC-21149 treatment than in all other treatments, reflecting superior cotton fleahopper control.

At Waco, Tex., in field tests Union Carbide UC-21149 granules applied in the seed furrow at planting at 1.0 pound per acre gave thrips control equal to that of a similar treatment with phorate at 1.2 pounds per acre. Bidrin, American Cyanamid compounds CL-47470 and CL-47031 each at 0.1 pound per acre, phosphamidon at 0.2 pound, Mobil Chemical MC-A-600 at 1.0 pound, and toxaphene at 1.0 pound plus DDT at 0.5 pound per acre, gave good thrips control with no difference among treatments. At Stoneville, Miss., UC-21149 and Dow's Nellite applied as granules in the seed furrow at planting at 1 pound per acre gave good control of light to medium thrips infestations. General Chemical compounds GC-9160 and GC-3707, and Mobil Chemical MC-A-600 at 0.5 pound, Shell SD-9129 at 0.25 pound, and American Cyanamid compounds CL-47031 and CL-47470 at 0.1 pound per acre, gave good control of light thrips populations.

In field experiments at Waco, Tex., Bidrin at 0.1 and 0.2 pound, Geigy G-13005 at 0.25 pound, and Mobil Chemical MC-A-600 at 1.0 pound per acre gave cotton fleahopper control equal to that obtained with 1.5 pound of toxaphene plus 0.75 pound of DDT. American Cyanamid compounds CL-47031 and CL-47470 each at 0.1 pound, phosphamidon at 0.2 pound, and trichlorfon at 0.5 pound per acre were less effective.

In comparative studies at College Station, Tex., with $P^{32}$-labeled Bidrin and Di-Syston, Bidrin had more systemic activity from soil and stem treatment than Di-Syston. However, studies of the metabolism in soil indicated that Bidrin is detoxified more rapidly than Di-Syston. Aphid bioassay and radioassay studies indicated that Bidrin is taken up much more efficiently by cotton plants by stem treatment than by soil injection. Also, a lanolin formulation applied to cotton stems appeared to release the Bidrin slowly enough so that new growth was toxic to aphids.

In a survey by Stoneville, Miss., laboratory personnel, a resistant population of the spider mite, Tetranychus telarius, was found at Minter City, Miss. The resistant mites were found on a plantation which has had a chronic mite problem. Several recommended miticides such as demeton, chlorobenzilate and Kelthane failed to give satisfactory control. In one test phorate spray at 0.5 pound and 10% phorate granules at 20 pounds per acre gave good reductions of the resistant population.

In small field tests at Florence, S. C., Guthion plus Ethyl Guthion at 0.5 pound, Meta-systox at 0.375 pound, Ethion at 0.5 pound, carbophenothion at 0.5 pound, and demeton at 0.375 pound, gave satisfactory control of the carmine mite, Tetranychus cinnabarinus.

At Waco, Tex., the following materials gave good control of the desert spider mite (Tetranychus desertorum), 1, 3, 7 and 15 days after treatment; Parathion at 0.25 pound; Imidan, at 0.25 pound; Guthion at 0.25 pound; Guthion plus Ethyl Guthion at 0.125 plus 0.125 pound; Bidrin at 0.1 and 0.2 pound; Niagara Nia-9203 at 0.25 pound; and Shell SD-7438 at 0.5 pound per acre.

In tests at Tucson, Ariz., American Cyanamid CL-47031 applied to cotton stems in a lanolin paste at the rate of 5 mg. per plant gave 72-hour mortalities of 77, 92 and 78% when adult lygus bugs were placed on the plants 2, 7, and 14 days after treatment.

C. Biological Control.

1. Boll Weevil. Disease in boll weevils caused by Mattesia sp. was introduced into populations in field cages at State College, Miss. Spores of the disease were incorporated into a feeding stimulant mixture and sprayed on plants in 30"x30"x30" cages. In the first test only about 20% of the weevils contracted the disease. Temperatures of over 100° F. and very low relative humidity during the days of the test were partially responsible for the low rate of infectivity. In the second test conducted when daytime temperatures were around 90° F., about 50% of the weevils contracted the disease. An improved formulation of feeding stimulant, Mattesia spores, agar, sugar and water, prepared as a granular material and applied to the plants, resulted in about 77% mortality in the laboratory and about 67% mortality in two field cage tests. The additional effects of reduced oviposition and transmission of disease to progeny by infected females adds to the effectiveness of the disease in population suppression.

2. Other Insects. A polyhedrosis virus controlled bollworms in field tests at Brownsville and Waco, Tex. The laboratory propagated virus was effective against both Heliothis zea and H. virescens. In three experiments on cotton at Brownsville the virus compared favorably in control with several insecticides recommended for control of the two species. A dosage rate equivalent to 100 diseased larvae per acre applied as a spray at 5-day intervals was almost as effective as a dosage of 1000 diseased larvae per acre. In an experiment at Waco the virus gave fair control but was less effective than mixtures of toxaphene and DDT or TDE.

High degree of parasitism of Heliothis sp. eggs by Trichogramma sp. was observed in late September and early October at Brownsville, Tex. Sixty-seven percent of the eggs collected on tomato plants were parasitized, 45% on corn, and 82% of a limited number collected on beans. Of the total collected from the different host plants, 56% were parasitized, with an average of 1.5 parasite adults emerging per parasitized egg.

Large parasite populations were found on Heliothis species on wild hosts at Brownsville, Tex. Early spring collections of H. zea from lettuce failed to show any parasitism, undoubtedly due to extensive use of insecticides on this crop. In the absence of insecticide use, more than 50% of the Heliothis larvae collected from wild tobacco were parasitized and in one collection of five larvae on March 1, all were parasitized. Thus the spring buildup of parasite populations on Heliothis on wild hosts may be of substantial importance for their migration to parasitize bollworms on cultivated hosts in the early season.

Geocoris pallens was a good lygus bug predator in laboratory tests at Tucson, Ariz. A 5 to 50 ratio of Geocoris to first instar lygus nymphs resulted in a 73.8% reduction of the lygus bugs. A ratio of 5 to 30 Spanogonicus albofasciatus to first instar lygus bugs nymphs resulted in a reduction of only 4.8%.

D. Insect Sterility, Attractants and Other New Approaches to Control.

1. Boll Weevil. ENT 50896 showed promise as a boll weevil chemosterilant at State College, Miss. Its general overall effectiveness and low toxicity to the weevil indicated it may be far superior to apholate, the current best material.

A mixture consisting of apholate, agar, sugar and crude feeding stimulant, showed promise in sterilizing boll weevils in laboratory tests at State College, Miss. The mixture was sprayed or dusted on seedling cotton plants. Weevils were exposed to the seedlings for five days and then fed on untreated squares for two weeks. The eggs obtained were observed for hatch. Both spray and dust treatments increased the preoviposition period, decreased the number of eggs laid, and reduced egg hatch. Complete sterility was not obtained in the preliminary tests.

In studies at State College, Miss., hempa was erratic as a male chemosterilant. Sterility was obtained at the 5% level with dips, at the 10 µg level with injection, and at the 5000 ppm level with feeding, but results could not always be reproduced. Mammalian toxicity is low with this compound.

Apholate was superior to tretamine and hempa as a chemosterilant dip for boll weevils in tests at State College, Miss. Although tretamine did better in sterilizing boll weevils it produced approximately twice as much mortality as the apholate dip. Hempa was considerably less toxic to the weevil but did very poorly in inducing sterility as a dip treatment.

Aggressive sex behavior by the female boll weevil was demonstrated in a series of tests in Florida and Mississippi. A windborne pheromone apparently secreted by the male attracted females from up to 95 feet away. Both week-old virgin females and overwintered fertile females responded. The aggressiveness of the female may extend to elaborate tactile behavior in the alerting of the male before copulation.

In studies at State College, Miss., Gossypium armourianum and G. tomentosum were lower in the boll weevil arrestant/feeding stimulant than Delta Pineland Smooth Leaf. In addition, four experimental lines, 256-1, 256-3, 256-4, and 256-8 contained less arrestant/feeding stimulant than DPSL. Cotton lines SA 189 (UA 7-21), SA 180 (Upland UA 7-1), and SA 136 (GSP 2-6-14), previously found lower than DPSL in stimulation of oviposition, also were lower than DPSL in arrestant/feeding stimulant.

A highly active boll weevil feeding and oviposition deterrent has been extracted with water from the calyx of Rose of Sharon (Hibiscus syriacus) buds at State College, Miss. This material reduces feeding on and oviposition in cotton squares treated with it. The mechanism of reception appears to be tactile as taste or preliminary probing rarely occurs on agar-water plugs containing effective levels.

2. Pink Bollworm. Metepa-sterilized males reduced pink bollworm populations in cage studies at Brownsville, Tex. Release of laboratory-reared pink bollworm moths at a rate of 180 sterile males (Metepa-treated) to 20 pairs of untreated moths (9:1 ratio) reduced the $F_1$ population 81% from that of the check in 1/200-acre cages with 3 treatment replicates. There was a 2.6 fold population increase in the cages with the treated insects because of high reproductive potential and favorable environment. This increase compared with a 11.8-fold increase in the cages with the untreated population, indicating that a 91.5% reduction would be required to cause a population decline. This could be obtained by increasing the ratio of sterile to normal males. Because the expected rate of increase in field populations is less than that of the caged populations, a 9:1 ratio might be sufficient to reduce a field population.

3. Other Insects. Sex lures were discovered in female moths of the bollworm, tobacco budworm, and cotton leafworm at Brownsville, Tex. Bollworm males showed no response when exposed at different times of day to the oily residue extracted with methylene chloride from the last abdominal segments and ovipositors of females. Results were similar with different solvents or when the females were crushed on filter paper. However, strong responses were obtained when males were exposed to gases emanating from the detector outlet of a gas-liquid chromatograph containing the extract. The males responded by vibrating their wings, extending their claspers, attempting to mate with each other, and flying to the source of the gases. Similar responses were obtained with a limited number of tobacco budworm moths. Cotton leafworm male moths responded to a raw extract from the females and to the gases from a chromatograph containing the extract.

E. Evaluation of Equipment for Insect Control and Detection.

1. Boll Weevil. The overall efficiency of a flail-type boll weevil infested square removal machine in tests conducted by the Agricultural Engineering Research Division at State College, Miss., was 84.2%. The machine was operated a total of 40 hours in field plot tests with only minor mechanical difficulties. When operated at a speed of 1.75 mph little plant damage was observed until the height of the plants exceeded fifty inches.

In studies at Stoneville, Miss., application of insecticides by helicopter to small cotton fields in wooded areas appeared to be a highly efficient treatment method for boll weevil control. Field population records and results of field cage tests in small isolated cotton fields treated with methyl parathion by helicopter indicated that this application method would be very desirable in areas where many small fields require treatment. It would be especially appropriate in a fall weevil control program. In field cage tests, 93.6% control of boll weevils was obtained with a swath width of 100 feet. Ninety-seven percent control was obtained with a swath width of 76 feet.

2. Bollworms. For many years more bollworm moths than tobacco budworm moths were collected in black light traps at Brownsville and Waco, Tex. This was the case even in recent years when during certain periods a high percentage of the population on cotton was the tobacco budworm. Previously it was assumed that the difference in numbers collected was due to the predominance of the bollworm in the populations. Now it appeared possible that bollworm moths might be more attracted to black light than tobacco budworm moths. Preliminary tests were conducted at Brownsville to explore this possibility. Laboratory reared 1- to 3-day old moths were released 80 feet from a black light trap in a 1/6 acre cage of cotton. Forty to 70% of the released Heliothis zea moths were collected in the trap while only 10 to 20% H. virescens were recovered. At Waco, Tex., in 1963, 2,962 tobacco budworm moths were collected in a black light trap operated from April through November. This is approximately three times the total number, 986, collected during the previous seven years (1956-1962).

F. Varietal Evaluation for Insect Resistance.

1. Boll Weevil. One hundred additional cotton lines were tested for boll weevil antibiosis with lyophilized square powder technique at State College, Miss. Eight lines produced weevils weighing less than 10 mg. (DPL Standard, 11.09 mg.). In one line 17 days were required for peak adult emergence (DPL Standard, 15.5 days). However, in 10 lines only 13 days were required for peak adult emergence. Kekchi continued to produce weevils less than 10 mg. in weight. The technique detected antibiosis present in Pima S-2 seedlings and in Gossypium thurberia and bolls for both criteria--days required for peak adult emergence and weevil weight.

In studies at State College, Miss., nonpreference for feeding and oviposition exhibited by the boll weevil for Rose of Sharon appeared to be due to the presence of a highly active water soluble anti-feeding compound in the calyx. Absence of or presence of only a low amount of an attracting substance and presence of a relatively high concentration of repelling substance appeared to be contributing factors to this non-preference. Nutrition furnished by Rose of Sharon buds and capsules was adequate for weevil development. However, adults were small (7-8 mg) and required a long development period (20 days).

Four of six cotton lines continued to show fewer boll weevil egg punctures than Delta Pine Smooth Leaf in replicated tests at State College, Miss. One of the four is a glandless stock and two are Sea Island lines. Mississippi field weevils oviposited proportionately fewer eggs, expressed in percent of those laid on DPSL, than laboratory-reared weevils on all lines except Pima S-2. Use of frozen squares tended to reduce oviposition more on S. I. Seaberry than on DPSL.

2. Bollworms. Effects of cotton plant characters are promising in control of both Heliothis virescens and H. zea in studies at Brownsville, Texas. Caged plants showed that nectariless and glabrous cottons caused a significant reduction in oviposition of H. virescens. Tests reported previously showed that response of H. zea to the nectariless and glabrous characters was very similar to that of H. virescens. Tests with pink bollworm showed a 37% reduction in mines due to the nectariless character but no significant difference between glabrous and hirsute cottons. In further laboratory tests on plant pigments, a diet containing 0.2% gossypol resulted in 78% mortality of both H. virescens and H. zea. Quercetin and rutin were more toxic to H. virescens than to H. zea. Chemical analysis of cotton leaves and squares showed free gossypol contents of different experimental strains ranging from 0.02% to 0.38% in large squares and from 0.04% to 0.52% in leaves.

Experimental strains of cotton resistant to insects continued to show promise at Brownsville, Tex. Further work with experimental strains of cotton in cage tests confirmed previous findings that nectariless and glabrous cotton limited populations of cotton leafworm, cabbage looper, and bollworms developing on them. The nectariless character reduced oviposition compared with that occurring on plants with the usual extrafloral nectaries, and the absence of epidermal hairs was even more effective in the reduction of numbers of eggs laid. When both characters were incorporated in a single strain the reduction in numbers of eggs deposited on the plants was very striking. In randomized single-row plantings, bollworm moths laid fewer eggs on a nectariless strain and on a nectariless-glabrous strain than on any of 13 other cottons except a Pima variety. Bollworm infestations are lower on Pima than on Upland varieties probably because of a higher gossypol content. Results of laboratory tests with synthetic diets indicated that it may be possible to use the plant pigments, gossypol, quercetin and rutin in developing plant resistance to the bollworm.

At Brownsville, Tex., plantings of cotton strain 1514, which is glabrous and nectariless, in plots replicated four times in each of 4 different fields showed a marked reduction in bollworm infestation from that on commercial varieties. Although the experiment has not been completed, results of 5 inspections at 3 to 4 day intervals showed lower numbers of eggs, larvae and damaged squares on strain 1514 than on commercial varieties in all fields. A high cotton fleahopper population developed on Delta Pineland--15 in one field--but the infestation in 1514 remained low. At Waco, Tex., cotton fleahopper populations were significantly lower in 1514 plots than in plots of two commercial varieties. In another test the infestation was below the injurious level in the 1514 plots but was above this level for 3 weeks in two commercial varieties. In studies at Brownsville four experimental cottons which inhibited bollworm larval growth in greenhouse tests, also, were effective in reducing larval weight compared with larvae developing on M-8 and M-8 glandless strains in field cage tests. Larvae developing on M-9 glandless plants made the greatest gains in weight.

Gossypol content of cotton leaves influenced bollworm development in laboratory feeding tests at Tucson, Ariz. Larval mortalities after 14 days of feeding on leaves of 9 varieties or strains of cotton with different gossypol contents were compared. Mortality on a high gossypol strain (1.075%) was 83%, on an intermediate gossypol strain (0.101%) 53%, and on a low gossypol strain (0.038%) 37%. High gossypol content in cotton leaves was associated with infertile bollworm eggs. Moths produced from larvae reared on leaves of Acala 4-42-77 glandless laid all fertile eggs, whereas those from larvae reared on the genetically closely related Acala 4-42-77 glanded laid all infertile eggs. The latter, glanded strain leaves, contained 2.6 times as much gossypol as the glandless strain.

Cotton leafworm larvae fed for 9 days on square powder diets from three glandless lines and $D_2$723 were larger than those fed on DPSL in tests at State College, Miss. They averaged approximately 10 mg on DPSL and ranged from over 12 to over 16 mg on 3 other lines. For some unknown reason there was no survival on Hopi M5-11.

Cotton leafworm moths selected only glandless lines for oviposition in a natural infestation of a field containing 329 different lines of cotton. As larvae hatched and damage occurred, only the six glandless lines were damaged, one glandless line less than the others. A laboratory study of oviposition where only M-8 and M-8 glandless cottons were available for oviposition showed twice as many eggs oviposited on M-8 glandless. Laboratory studies with larvae showed glandless lines to rank first, third, fourth, and sixth out of nine lines in amount of leaf tissue consumed when larvae were confined on each line.

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## COTTON PLANTING, FERTILIZING, HARVESTING, HANDLING OPERATIONS AND EQUIPMENT AND PEST CONTROL
Agricultural Engineering Research Division - ARS

Problem. Two large items of expense in cotton production are seedbed preparation and planting. Preliminary work has indicated that more than optimum primary tillage is being done in many cotton areas resulting in wasted horsepower, unnecessary soil compaction, moisture losses and increased cost. In planting, more precision and timeliness is needed to assure the rapid emergence of uniform stands. This will require more basic knowledge of the micro-environmental requirements of the cottonseed, and more automatic sensing and control mechanisms in planting equipment. More precision in the control of the seedbed shape, size, and position will also have a direct bearing on the economical use of new and more potent pesticides.

Engineers are continually obligated to develop application equipment for new agricultural chemicals in cooperation with scientists in the biological disciplines. The outstanding problem in cotton pest control equipment is currently the application of more toxic chemicals in such a manner that the crop will not be damaged, an economic quantity will be effective, and toxic contamination will be minimized. Shallow soil incorporation and underground application shows promise of solving some of these problems with some chemicals, but the optimum location and degree of incorporation has not been determined; and the equipment for accomplishing specific degrees of incorporation has not been developed.

Although previous research has discovered cultural techniques and developed mechanical procedures for improving the efficiency of cotton harvesters, field losses are currently the most serious problem in cotton harvesting equipment. A recent survey by the National Cotton Council revealed that field losses in machine picking still average 11 percent. This is the equivalent of 3.3 cents per pound in the cost of production or a loss of 110 pounds of lint/acre in cotton yielding 2 bales per acre. Quality preservation is still a challenge to researchers also. Although cleaning in gins can remove most of the moisture and trash resulting from machine harvesting, these contaminants should be left in the field. If lint could be kept free of excess moisture and trash, quality-damaging drying and cleaning could be minimized.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of cotton production and harvesting in cooperation with experiment stations and the farm equipment industry. At cotton mechanization research projects located at Auburn, Ala., Shafter, Calif., State College, Miss., Stoneville, Miss., and Lubbock, Tex., a portion of the work at each project is devoted to study of cotton planting and fertilizing methods and equipment including crop residue disposal. Uniformity of emergence, desirable seedbed

shape for later operations, and effect of planting and fertilizing practices on mechanical harvesting are studied. The Federal scientific effort devoted to research in this area totals 3.4 professional man-years.

Studies on effects of electric glow-discharge radiation of cottonseed as a means for improving seed germination is being conducted at Knoxville, Tenn., at the rate of 0.4 professional man-years.

A limited program of engineering research on equipment for application of insecticides, fungicides, and herbicidal and mechanical weed control is underway and is being conducted at Auburn, Ala., Stoneville, Miss., Shafter, Calif., and Lubbock, Tex. Specific attention to boll weevil control is underway at State College, Miss. The use of electric traps for attracting and collecting various cotton insects is being studied at College Station, Tex. The Federal scientific effort devoted to research in this area is 4.7 professional man-years.

Major engineering effort is being given to the development of new methods and equipment for mechanically harvesting and handling cotton at research projects located at State College and Stoneville, Miss., Auburn, Ala., Lubbock, Tex., and Shafter, Calif., in cooperation with USDA Cotton Ginning Laboratories. The Federal engineering effort devoted to research in this area totals 5.9 professional man-years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

### A. Cotton Planting and Fertilizing Equipment

1. Complete crop residue disposal by destruction of the roots as well as the stalks has been found desirable in previous research, but adequate and economic equipment for this operation has not been available. This year in Mississippi promising results were obtained in preliminary field tests of a commercial machine which shreds the plant with twin horizontally rotating blades and uproots and masticates the stubble and root crown with an integral rotary tiller. Preliminary design and development was begun on another machine to dispose of the entire plant without shredding by depositing it in a vertical subsoil trench.

2. Precision tillage (deep subsoiling under the row) increased cotton yields and plant response again in California, particularly in lighter soils. The two most important factors for success of precision tillage were found to be proximity to the drill row and sufficient depth to penetrate through the compacted layer.

Precision tillage gave slightly higher yields than other tillage methods and slightly better than last year at 2 locations on fine sandy loam soils at Lubbock and Stoneville. Although disk harrowing following other primary

tillage treatments resulted in a finer seedbed and better stands, yields were lowest in these and the middlebreaker plots.

3. A minimum tillage system, used for the second year in California required less than 30 percent of the horsepower hours of the normal system. The draft requirements for precision tillage (20" to 24" deep) were found to be 2120 pounds per shank in Hesperia fine sandy loam and 4070 in Panoche clay loam soil.

4. In a study of transferring soil layers, Tunica silty clay, a stratified clay over sand deposit, was mixed thoroughly to a depth of 30 inches with specialized equipment in Mississippi. Mixing improved infiltration rates, internal drainage, and reduced the power required for plowing 35 percent. Although moisture was not sufficient to settle the excavated and inverted layers of soil in time for proper smoothing, yields were improved significantly over the standard practice of shallow bedding; but subsoiling to comparable depths gave the same results. The long-term effects of the soil mixing will need to be evaluated.

5. Liquid fertilizer equipment was adapted to a tractor-mounted 4-row lister at Lubbock for applying fertilizer simultaneously with bedding.

6. Precision depth planting was accomplished at Lubbock by a newly designed planting attachment that regulated the seed furrow opening shoe depth by a threaded rod adjustment and was controlled at a constant height with a gage wheel operating on the bed by the side of each opener. Several commercial and one experimental press wheels were tested for the pressures they transmit to the covering soil during planting. All of the press wheels except the experimental wheel produced pressures above 2 psi which has been found to hinder emergence under certain conditions in previous research results.

Similarly, under the planting conditions at Shafter, the use of any soil surface compacting tool following planting was detrimental to stands. Crust strength varied from 37 psi for no compacting wheel to 307 psi following a rubber press wheel. Hill-dropped cotton emerged through hard crusts better than drilled cotton. The loss of cotton seedlings to disease was found to increase with higher rates of seeding and with closely spaced hills.

7. At Lubbock cotton came up two days earlier from pre-emergence asphalt mulch plots, and a slight increase in yield was obtained where mulch was sprayed as a pre-emergence application or when applied pre-emergence plus post-emergence. Yields were reduced by mulch where it was applied as a post-emergence treatment only. Although moisture retention was better, there was no significant increase in temperature when rates were increased from 50 to 300 gallons per acre.

One of the greatest drawbacks to experimental synthetic mulches and other chemicals is often the cost of material. The amount of petroleum mulch required was reduced to 20 percent at Stoneville by the precision placement of spots over hills of hilldrop cotton. The hilldrop mechanism of the planter was timed with an air solenoid valve in the spraying system. Results from the small spots of application were equal to those from the continuous band application.

B. Pest Control Equipment for Cotton.

1. Chemical weed control has made it feasible to grow cotton broadcast or in very narrow rows in the high plains area of Texas. At Lubbock, a pre-emergence chemical, Diuron, was sprayed broadcast over a plot of cotton planted in 9 in. rows at the rate of 1 lb. per acre, and the block was sprinkle irrigated to activate the chemical. Excellent control of broadleaf weeds was obtained and the cotton was grown without cultivation or hand hoeing. Hand hoeing was significantly reduced in 40 in. row cotton by the use of a post-emergence spray of Diuron plus a surfactant.

Laboratory and field evaluation of granular herbicides in Alabama showed that slight changes in nozzle height did not materially affect granule distribution. Across-the-row distribution was non-uniform and varied between two nozzles of the same design. Liquid-treated plots required slightly less hoe time than granule-treated plots. The machine loading time for handling granules was 0.5 min. per acre compared to 3.3 min. for handling liquids.

Studies of nozzle wear with 4 different nozzle materials were concluded in Mississippi and Alabama this year. Results showed that stainless steel or hardened stainless steel orifices are much more resistant to wear and are more economical than brass, particularly when wettable powder formulations are used. Brass tips should be recalibrated frequently to maintain the correct application rate. The highest rate of flow increase occurred during the first 3 hours of spraying. No relationship existed between nozzle wear and spray pattern characteristics as long as the pressure was maintained.

In flame weed control studies, further modifications were made in methods of mounting and operating the experimental middle burners reported last year. Preliminary tests were also conducted to see if this device might be used to destroy boll weevils in fallen squares. In cooperation with the USDA Boll Weevil Laboratory, temperature measurements were made within the squares at different tractor speeds. Results indicate that with speeds less than 1 mile per hour the middle burners would give a satisfactory kill, but further study is needed.

Fungicides for boll rot control were studied in cooperation with the Pathology Department at Stoneville. A quantitative measurement of chemicals deposited on bolls was developed. The system consists of correlating volumetric displacement of the boll to boll surface size. Laboratory equipment was developed to wash a fluorescent dye deposit from the boll and at the same time read the liquid displacement of the boll. Dye concentration can then be determined in a fluorometer and can be recorded as pounds of material per square unit of boll surface area.

A two-row cotton picker chassis was stripped of picking equipment and adapted to the application of pesticides in cooperation with industry engineers in Mississippi. Equipment included a 240 gal. tank, 12 row boom, and post-emergence directional spraying rigs. The machine provided adequate power and vertical clearance, good visibility for the operator, easy control of boom height and adequate lifting capacity as well as better utilization of equipment.

2. Refinements were made in the combination underground chemical applicator and planter to give more uniform application under a wider variety of planting conditions. The tri-band method of application of EPTC gave good control of nutsedge and annual weeds. Seedling Johnsongrass was also controlled in one test by applying Diuron in a tri-band. The work will be concluded on this specific equipment after one more year's research in Mississippi if the results are consistent with those of the past two years. Several methods of post-emergence sub-surface application of herbicides were investigated for weed control in skip row cotton. Two methods were deemed worthy of further investigation: (1) the Stoneville sub-surface applicator attached across the beams of a conventional cultivator, and (2) a small disk coulter followed by a straight stream nozzle spraying into the slit created by the coulter which were placed 4 in. apart. The latter device offers promise if combined with mechanical cultivation. Wide 26 in. sweeps gave good mechanical control.

Study of powered rotary tillers for soil incorporation of chemicals was continued on a limited scale at Shafter. Improved techniques were devised for studying the uniformity of incorporation with tracers. Results showed more uniform mixing with the knife and angle iron blade rotors than with the tine rotor. Efficiency of mixing was found to increase with the relative velocity of the rotor blade.

Two methods of incorporating fungicides in soil for seedling disease control were found to be superior to the "in furrow" spray at Shafter. A 4-in. wide rotary tiller was used to incorporate liquid and granular fungicides in comparison with conventional "in furrow" applications of granules and sprays. In final stand counts, soil incorporation of spray and granule formulations of the fungicide PCNB rated first and second, respectively. Granules and spray applied "in furrow" and on the covering soil in the usual manner ranked third and fourth in that order. Spray and

granules applied only in the bottom of the seed furrow and the nontreated check ranked last.

The effectiveness of nematocides was increased when combined with precision tillage in California, either as a sidedress application or as a deep application behind the subsoil shank. The latter was better than sidedressing.

3. Studies on mechanical methods of destroying fallen cotton squares were conducted at the Boll Weevil Research Laboratory, State College, Mississippi. An experimental, tractor-mounted, flail-type machine was designed, constructed and tested to determine its effectiveness for boll weevil control. Few major mechanical difficulties were encountered during the field test period. The overall square pickup efficiency for the testing season was 84.2 percent. The efficiency in the cotton middles was 92 percent, and in the drill area underneath the plants, 63 percent. The boll weevil control which was obtained was comparable with insecticide treatments as long as the migration of the insect was not a factor in the experiments. An improved model of the experimental machine is presently under construction. The major improvements include rotary brushes for moving the squares from underneath the plants, and an improved drive for the machine.

Studies on the effects of middle flame cultivation on the immature boll weevil were conducted at State College, Mississippi. Infested squares were treated at various ground speeds with a middle flame cultivator which is designed primarily for weed control. The flamer was tested using one burner (2 nozzles) following by a 16-in. hood, one burner followed by a 34-in. hood, and 2 burners and hoods in series. Significant reduction in boll weevil emergence from the treated material was obtained at low ground speeds with each burner and hood arrangement. The highest ground speed which gave a significant reduction was 1 MPH with 2 burners and hoods in series.

Studies on the effects of sunlight on fallen cotton squares were conducted at State College, Mississippi. Fallen squares were collected and samples were placed in locations so that each would be exposed to either total shade or total sunlight from 10 a.m. until 3 p.m. Samples were placed on black painted soil as well as unpainted soil. No significant differences in boll weevil emergence were obtained.

C. Cotton harvesting equipment

1. In a continuing study of harvest aids in California, cotton was artificially wilted by applying a desiccant and harvesting 48 hours later. This treatment had no advantage over regular defoliation nor regular desiccation.

In a topping and vertical pruning test in Mississippi, both treatments reduced boll rot slightly but also reduced yield. Although there was no lodging problem this year, topping and vertical pruning permitted more sunlight to reach the inner areas of the plants for the first two weeks after treatment; however, there was evidence that more new growth occurred in the topped plots.

In further study of bottom-defoliation and bottom-picking methods at Stoneville, grid bars were constructed to keep the cotton from contacting the top eight rows of spindles. This method allowed about 2 inches more clearance for the plant and overcame the stalk breakage experienced with the spindle shield; however, the Ret Bar pressure plate gave the highest picking efficiency. Bottom defoliation was fairly effective this year, but the extremely dry conditions made it unnecessary in most fields. The Rust picker was used in this test by removing the top crowder channels and opening the top of the unit. This is a very good method of bottom-picking with this machine. Bottom defoliation and bottom picking resulted in a sample with lower trash and moisture content than regular picking.

A number of studies have been conducted to determine the effects of grass on the quality of machine-picked cotton. Results vary with areas, types of grass, degree of infestation, growing conditions and other factors. For the second year cotton was picked from moderately grassy and clean fields at Stoneville with no important quality differences when picked with a tapered spindle machine. Most of the late maturing grass had become etiolated by picking time. The cotton was ginned both with and without lint cleaners and spinning tests will be conducted to determine the effect of grass on the yarn. Harvesting efficiency was lowered slightly in the check plots where grass and vines infested about 25 percent of the hills compared with less than 5 percent infestation in the treated plots.

2. Cotton picker head torque requirement tests were continued at Stoneville with five greases. These five greases were used in temperatures at 32° F. or below for 30 minutes running time. A high torque measurement of 40 horsepower to start one picker head was recorded at the lowest temperature. A picker with grease-lubricated spindles was serviced and samples taken at regular intervals while picking to determine the amount of contamination on picked cotton. Six samples and a hand-picked check were ginned and determinations of oil content made. After 3 hours, the machine-picked cotton had very little more oil than the hand-picked check. Most of the grease seemed to be dispersed during the first hour of picking. Although lint color was adversely affected, there were no adverse effects from the grease on spinning and fiber properties.

A number of picker attachments were evaluated at Stoneville. A different type of plant lifter device, consisting of longer lifters with rubber tips that pick up low limbs, slightly increased the picking efficiency of a two-

row picker. Behind the lifters are wheels with rubber lugs that lift the ground cotton and lower limbs. Additional wheels that replace the shields are also available for late picking and gleaning. These units increased picker efficiency from 88.3 to 91.8 percent and picked up 0.2 bales per acre after the cotton had been picked for the last time. Several of the attachments for scrapping cotton from the ground along with the final picking were in use and were successful in most cases; however, considerably more trash was usually added to the machine-picked cotton and the picker parts are subjected to more wear. A device which automatically adjusts the picking unit height on a two-row picker seemed to work satisfactorily in the field, after minor changes were made. The Ret Bar compressor sheets increased the picker efficiency over the standard compressor sheets.

The spinning performance of cotton harvested with three types of picker spindles was compared in the last year of a 3-year study in California and Mississippi. Less trash was harvested with the smooth square spindle machine. The number of ends down per thousand spindle hours and manufacturing wastes were slightly lower for hand-picked cotton at both locations; however, the classers grade of hand-picked cotton in Mississippi was one grade lower than for any of the machines. Complete reports on these tests will be published in the coming year.

Cotton gleaning machines were used over a wider area this year because of high yields and good salvage operating conditions, often yielding a bale on 4 to 10 acres. Ginning was still the greatest problem of gleaned cotton even though grades and prices were good. In a California test, the efficiency of a notched belt gleaner was found to be constant over a speed range of 3 to 6 m.p.h. Seed cotton trash decreased as forward speed increased.

Four varieties were grown for stripper harvesting in Mississippi. Two storm resistant varieties with 50,000 and 100,000 plants per acre, grew a small stalk and harvested very well before frost with a flexible roll stripper. The open boll varieties were planted at 60,000 and 85,000 plants per acre. They grew to a height of 48 to 60 inches and did not harvest efficiently with the stripper. Yields of the four were 1.5, 1.7, 1.9 and 2.0 bales per acre, respectively, for Arkansas stripper 60-2, Lankart 57, Rex smooth-leaf and Stoneville 7A varieties. This year's results indicate that a smaller, early-maturing, high-yielding plant with good fiber characteristics will be needed for stripper-type harvesting in the sandy loam soils of the mid-south.

3. A broadcast finger type stripper was developed at Lubbock and mounted on a cotton picker chassis for harvesting the broadcast planted cotton which has been successfully grown for several years in the High Plains area. This machine performed satisfactorily in broadcast cotton and in other row spacings from 5 to 40 inches. The USDA green boll separator was designed into the elevating system of this stripper. Power measurements on the improved

green boll separator were made with strain gages and associated recording equipment in comparison with the conventional stripper elevator. Horsepower requirement for the experimental unit was about five horsepower more than for the conventional elevator. This additional power is required for air velocity.

4. Sources of trash studies were continued. In Alabama, cotton from plots where the leaves, ground trash, and boll bracts were removed had one-half as much fine trash as cotton from defoliated plots, one-third as much as cotton from defoliated-desiccated plots, and two-thirds as much as hand-harvested cotton. In the well-defoliated cotton, the trash in the harvested cotton consisted of 19 percent leaves, 14 percent bract, 3 percent stems, 58 percent burs, 6 percent unknown trash, and no ground trash. Desiccation of second growth increased the total and fine trash of both the wagon sample and the ginned lint.

Machine-picked cotton was composited and stirred in the trailer prior to cleaning and ginning to determine if such procedures would affect lint quality by mixing the trash which accumulates in the rear of a picker basket. No practical advantages were obtained. Since repeat results were obtained in the 2 years of study, no further work is scheduled under this project at Stoneville.

5. The basic study on the influence of plant characteristics on mechanical harvesting was continued at Auburn. Mechanical picker losses averaged 20 percent for bolls on limbs originating within 4 inches of the ground, 14 percent on limbs originating between 4 and 20 inches, and 8 percent from limbs originating above 20 inches on plants averaging 36 inches high. Horizontal boll location with respect to the vertical stem of the plant had little effect on efficiency. A 2-inch increase in drum height above the ground surface reduced machine efficiency 4.3 percent in a 20,000 plant population. The laboratory picker was modified and the relationship of spindle speed and picking efficiency was determined for one boll type. For spindle speeds of 700, 1,500, 1,900, 2,300, 2,700, 3,100 and 3,900 r.p.m., the efficiencies were 65, 88, 92, 97, 97, 98 and 94 percent, respectively. Preliminary data indicate that a 5-lock boll is picked more efficiently than a 4-lock type. Also, bolls pointing downward are picked more efficiently than bolls pointing upward. A torquemeter proved unsatisfactory for measuring the force to remove cotton from the bur. A pendulum was designed and constructed for measuring picking energy and measurements are being made of bolls from different varieties, but no data are yet available.

In a similar study at Stoneville, a different type of instrument was used to measure the force required to remove a lock of cotton from the bur. The carpel angle of each boll was also measured. Bolls from each of six varieties over a 3-year span were included in the test. Lankart 57 required the most force, while D & PL Smoothleaf required the least. There was no significant correlation between force and carpel angle although the force was greater for the low carpel angles in most cases.

In a continuing harvesting evaluation of six widely different varieties in Mississippi, conditions were more uniform and efficiencies higher than in the past. Lankart 57 continued to have very little preharvest loss and a lower picker efficiency than the others. The Acala variety produced more cotton than previously on a smaller stalk. D & PL Smoothleaf had the highest picking efficiency and lowest trash content but was highest in preharvest loss.

6. In field storage and handling work at Lubbock, a dump trailer, operating behind the stripper, eliminated the need of men in the trailer and proved to be a satisfactory method of dumping machine-stripped cotton for field storage. A study was made to evaluate the time and motion of this and other methods of handling machine-stripped cotton from harvesting to ginning. A tractor-mounted basket used in conjunction with the USDA boll separator-elevator also gave favorable results in these studies.

D. Electric Traps for Cotton Insects

Laboratory and field studies relating to the use of visible and near-ultraviolet energy for attracting and collecting various species of cotton insects were continued in 1963 at College Station, Texas. Studies were conducted in cooperation with the Texas Agricultural Experiment Station and the ARS Entomology Research Division Laboratories at College Station and Brownsville, Texas. The Physics Department, Texas A&M University, cooperated informally in certain phases of these studies. This project contributes to Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm".

In cooperation with entomologists of the Southwestern Cotton Insects Investigations, ENT, College Station, Texas, group response techniques and a Y-shaped test chamber were used to study intensity-wavelength relationships influencing phototactic responses of the boll weevil. No threshold irradiation energy level for induced responses to 365-mu stimuli was perceptible from 0 to 16 uu watts/$cm^2$. Response increased gradually within this range, becoming significantly different from no-stimulus response at levels greater than 16 uu watts/$cm^2$. The log energy level vs. response curve was approximately linear for levels greater than 16 uu watts/$cm^2$. Tests at other wavelengths (365, 490, and 615 mu) and energy levels (8, 80, and 800 uu watts/$cm^2$) indicated an experimental design using energy levels of 24, 160, and 800 uu watts/$cm^2$ and wavelengths at 25- to 50-mu intervals should provide data for plotting a true action spectrum of response. Action spectrum determinations are planned as the next phase of this work. Information obtained should be helpful in determining design parameters (quality and quantity) for lamps to be used as effective boll weevil attractants.

Work has continued in cooperation with biophysicists of the Physics Department, Texas A&M University, in developing techniques and equipment for determining spectral response characteristics of individual insects by use of the electroretinogram (ERG). Electronic and optical equipment have been assembled which

permit the viewing and recording of electric signals induced in the eyes of cockroaches by radiant energy stimuli. ERG studies are planned for the boll weevil, bollworm, and budworm in order to evaluate ERG techniques as a means of predicting whole-body response of insects to radiant energy stimuli.

Further assistance has been provided Texas Agricultural Experiment Station entomologists in the development of optical and electronic equipment to be used in studies of photoperiodic control of diapause of the pink bollworm.

Five projectors for monochromatic irradiation of insect cultures have been constructed, and qualitative and quantitative measurements of spectral emission characteristics are partially completed.

A thermopile and a thermal irradiation standard lamp were used to calibrate a phototube used for measurements of irradiation energy levels. This calibration provides a basis for measurements in absolute energy units, thereby facilitating comparisons of energy levels used in laboratory and field studies.

Studies on the response and physiological effects of light on the boll weevil were conducted in cooperation with the Entomology Research Division of ARS at the Boll Weevil Research Laboratory, State College, Mississippi.

Equipment was installed and calibrated for use in measuring light intensity. Preliminary tests were conducted with a Y-shaped tunnel in attempts to standardize procedures and to eliminate variables such as the pre-exposure dark period, exposure time, and insect food. Conclusive results were not obtained because sufficient numbers of insects were not available for the study. Some work is planned for next year when laboratory-reared insects are expected to be available.

E. Radiofrequency and Glow-discharge Treatment of Cottonseed

Limited studies were continued on RF and glow-discharge treatment of cottonseed in cooperation with Texas A&M University. Some glow-discharge or gas-plasma treatments accelerated germination of Empire WR cottonseed, but no improvement was noted in field emergence tests. One RF-treated lot produced a significantly higher yield. Otherwise there was no change in staple or yield data. RF treatments also showed some promise in alleviating a hard-seed problem in cotton. Limited work will continue on cottonseed treatment research.

The range of the 60-cycles-per-second glow-discharge treatment was extended and under laboratory conditions increased beneficial effects on early emergence were noted for Empire WR fuzzy and machine-delinted cottonseed. A series of tests on seed treated in a glow-discharge energized at frequencies above 60 c.p.s. were carried out and resulted in improved earlier emergence as compared to untreated seeds. There were no significant differences due to frequency. Exploratory field plantings showed earlier emergence for seed treated at two of the new 60-c.p.s treatments. A 3-year field test in cooperation with CR, ARS to investigate these new treatments will be started in 1964. A mechani-

cally planted and harvested field test of treated cottonseed will be started in 1964 at the Tennessee Agricultural Field Station in Milan, Tennessee in cooperation with the Department of Agricultural Engineering.

Empire WR and Lankart seed was harvested from plants grown from treated seed of the previous year. These seeds were given the same treatments as the parent seed had received and were returned to the Texas A&M Experiment Station for planting.

Hard-seeded samples of an experimental cotton variety (16-B-7) developed by CR, ARS, Stoneville, Mississippi were treated and returned to Stoneville for evaluation. The best level of glow-discharge treatment produced an 81 percent germination on the sixth day after planting as compared to 9 percent for the control seed. Future developmental work on this variety is being transferred to Knoxville, Tennessee which will enable much closer cooperation between AE and CR.

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## COTTON GINNING
Agricultural Engineering Division, ARS

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed and trash, packaging, and sampling to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Advances in cultural practices in the mechanization of cotton harvesting will depend to a great extent on continued research to develop adequate ginning equipment, improvements in present equipment, and improved practices in using equipment. The solution to many of the difficult problems of modifying the gin to meet the needs of mechanically harvested cotton are still ahead.

Cotton ginning problems are greatly influenced by the increase in rapid harvesting methods on one hand and the increased production rates in manufacturing, on the other. Modern methods in harvesting and manufacturing in the interest of reducing costs place more stress on the cotton fiber than ever before and more of a burden on the gin in coping with increased amounts of foreign matter and preserving the inherent quality of the fiber while preparing it for mill use. Among the more pressing problems are those growing out of modern methods of harvesting and handling cotton. They include means for reducing the power and labor requirements for gins and methods for dealing with air pollution and trash disposal as a result of handling large quantities of foreign matter. A method for evaluating seed cotton is also needed to serve as a measure of quality inputs to the gin for research purposes.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, materials handling engineers, and systems engineers engaged in both basic and applied research on the engineering phases of cotton ginning and handling. Seed cotton handling and storage research is currently being conducted at Stoneville, Mississippi. Research on seed cotton drying and seed cotton cleaning is being conducted at Clemson, South Carolina, and Stoneville. Conveying equipment and gin stand studies are carried on at Mesilla Park, New Mexico, and Stoneville. Research on gin performance and cotton quality is conducted at Stoneville, Clemson, and Mesilla Park. Lint cleaning studies are conducted at Stoneville and Clemson. Research on cottonseed handling is carried out at Stoneville, and waste collection and disposal studies are conducted at Stoneville and Mesilla Park. Research is cooperative with state experiment stations, Agricultural Marketing Service, Economic Research Service, industry, and individuals, as well as other Divisions in the Agricultural Research Service.

The Federal engineering effort devoted to research in this area totals 17.5 professional man-years. Of this number, 0.3 is devoted to seed cotton handling and storage, 1.9 to seed cotton drying equipment, 3.2 to seed cotton cleaning, 0.4 to conveying equipment, 2.1 to gin stand, 6.0 to gin performance and cotton quality, 0.5 to lint cleaning, 0.3 to packaging, 0.2 to sampling, 0.2 to cottonseed handling, and 1.9 to gin waste collection and disposal, and 0.5 to program leadership.

## PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is conducted in only two State agricultural experiment stations; namely, Oklahoma and South Carolina. The Department has been specifically concerned in this area for several years and has carried on the major program of research on the engineering phases of premarket cotton processing and handling.

The Oklahoma research involves the adaptation and testing of cotton ginning equipment, techniques and related operations for reducing the cost and delay in handling and conveying seed cotton on the gin yard and in the gin. In addition, evaluations are being made of the quality reductions associated with green and immature bolls in harvested cotton as well as determination of the effects that various combinations of cleaning, drying, and ginning machines have on returns to the producer.

The South Carolina studies are concerned with the development of new principles and techniques for ginning cottons. Characteristics and properties of seed cotton, lint, and seed related to the basic ginning processes are being investigated as well as the effects that various physical actions have on fiber and seed.

A total of 3.3 man-years are devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Seed cotton handling and storage

1. Some preliminary investigations were made at Stoneville in cooperation with the Cotton Harvesting Investigations of the types of trailers used in the sugarcane harvest. These trailers may be unloaded mechanically, thus effecting a labor savings. The principle involved appears to have some promise and will be investigated further for possible adaptation and use in handling seed cotton.

### B. Seed cotton drying

1. Any material which will change the electrical resistance of cotton will affect the accuracy of the automatic drier control system of the gin. Tests were made at Stoneville to determine if the commonly used insecticides and defoliants caused a specific effect on the electrical resistance of

cotton fibers en masse. The commonly used insecticides and defoliants studied in 16 separate experiments showed that normal use of these chemicals does not require special calibration of gin drying systems based on fiber electrical resistance measurement. However, variations in density will affect fiber resistances sufficiently that gin drying systems using the resistance measuring principle should be calibrated at and for some specific fiber mass density. Also, provisions should be made to maintain that density for proper system operation. The relationship between density and resistance was found to be logarithmic.

At Stoneville studies using an experimental zero-gradient drier to determine the effect of initial fiber moisture level before drying, air to seed cotton mass ratio, temperature, and exposure time upon quantity of moisture removed were conducted. Results showed the quantity of moisture removed to be directly proportional to initial moisture content. The factors, temperature and exposure, showed a logarithmic relationship to final moisture content of fiber under conditions of the experiment. Changes in air to seed cotton mass ratio caused small changes in fiber moisture content when compared to the effect of temperature and exposure.

Tests at Clemson using six moisture levels of drying showed that cotton ginned at a lint moisture content in the 8.0 percent range will preserve the use value of the cotton and yield satisfactory bale values for the producer when current ginning machinery recommendations are followed. When lint cleaning was used, cotton could be ginned at 8.5 percent lint moisture content without encountering rough preparation.

C. Seed cotton cleaning

1. Comparative tests at Stoneville showed that the micro-gin gave results comparable to a full-size gin at the laboratory. These tests confirm the theory that this small plant can replace full-size equipment in many instances as a research tool.

A serpentine cleaner developed at Stoneville was tested in the full-size gin. The tests show that the serpentine cleaner, which has no moving parts, is just as efficient as a conventional cleaner of the same open grid area.

Studies of the sequence of seed cotton cleaning machinery at Stoneville show that where a single unit 7- or 13-cylinder cleaner is used in conjunction with a stick and green leaf machine best cleaning is obtained when the stick machine precedes the cylinder cleaner. When two separate 7-cylinder cleaners were used with one immediately preceding the stick remover and one following, grade and cleaning results were essentially the same as when the unit stick remover was arranged to precede the 13-cylinder cleaner. With this fact in mind, it is believed best to have the cylinder cleaning divided into two units so that one 6- or 7-cylinder cleaner would precede and one follow the stick removal equipment. According to the experiments, this would not provide any better grade and cleaning, but would serve to better prepare the

cotton for passage through the stick remover by dispersing any wads for better feeding and less cotton loss during its passage through the stick removal equipment.

Spinning and fiber data did not show any consistent trend of important differences in fiber and spinning test results between 18 different overhead machinery arrangements tested.

Tests at Stoneville on a special strain of cotton bred for stripping in Arkansas showed that the normal machinery arrangement recommended for machine-picked cotton gave satisfactory results. The cotton was rather coarse, 5.7 micronaire, and 12 experimental ginning treatments all gave grades of Strict Low Middling. Stripping tests on a commercial rain-grown variety gave grades equivalent to machine-picked cotton for early season stripping. However, cotton stripped late in the season contained such a preponderance of large tough foreign matter that it was not practical to gin it. The experiments with stripping this commercial cotton demonstrated that the cottons which have been bred for spindle picking in the Mid-South area are not at all suited for stripper harvesting from a ginning standpoint.

A screw conveyor cleaner was modified and subjected to a second year of tests at Clemson. The cleaning grids under the conveyor which gave the greatest trash removal also gave the greatest cotton loss with the trash. The installation of a "breaker cylinder" immediately below the feed rollers in the feed control tended to single lock the cotton thus exposing more foreign matter and increasing the cleaning efficiency of the device. The cleaner had no effect on Shirley Analyzer or Colorimeter results. Classer's grade index and price per pound of lint, after reductions due to grass, for cottons subjected to the grids at one-half inch clearance from the conveyor were significantly greater than that of all other treatments. Measurable fiber properties were not affected by the screw conveyor cleaner regardless of cleaning plate design. Marked decreases in upper half mean length, strength and micronaire reading and a pronounced increase in short fiber content were noted in fiber samples from seed cotton removed with the trash by all cleaning plates tested.

It is an accepted fact that trash is removed more easily from seed cotton which has been separated into individual locks. A device designed to separate the locks of cotton was constructed at Clemson for tests. The device appeared to perform satisfactorily but the anticipated increase in cleaning efficiency did not materialize.

2. Evaluation tests were made at Clemson on an experimental drum-type tight lock separator and an auger-type separator, using seed cotton which averaged 3.48 percent of tight locks by weight. By removing the tight locks from the cotton the average bale value was increased $4.01 when using the drum-type separator and $1.89 with the auger-type.

D. Conveying

1. Tests at Stoneville using three vane-axial fans showed that, when vane-axial fans are operated in series, the static pressure delivered is slightly greater than the sum of the individual static pressures and the horesepower is slightly less than the sum of the individual horsepowers. The volume and static efficiency shows a slight overall increase with each additional fan stage. Series vane-axial fans are more efficient than comparable centrifugal fans.

Investigations of various materials handling techniques at Mesilla Park has yielded a principle of conveyance that appears to be more economical than conventional methods, and it is believed to be applicable to several materials handling situations in cotton gins. The principle involves the use of a number of low-pressure air-jets to lift and push the material along on a cushion of air. Preliminary trials conducted by the manufacturer of the conveyor showed that seed cotton, lint, gin trash, and cottonseed could all be conveyed using this principle. A pilot model of such a conveyor has been constructed and testing has begun. Initial results look very encouraging. Arrangements have been made to obtain a full-scale unit for further investigations this coming year.

E. Gin stands

1. Saw gins. Studies at Stoneville showed that the huller front of a high-capacity gin was an inefficient cleaner and it is doubtful that it is of sufficient value to warrant its continued use with machine-picked cotton.

Studies of the effect of high-capacity gin stands on cottonseed quality indicate that the germination is lowered slightly as a result of the mechanical damage incurred during the process of removing fibers from the seed.

Investigations were made to determine the feasibility of using reconditioned high-capacity, large-diameter gin saws. Saw diameters were reduced by one-sixteenth inch by repunching the saw teeth. The tests showed a slight reduction in ginning capacity, and an increase in power and energy requirements for the reduced diameter saws.

2. Roller gins. An electro-mechanical gage developed at Mesilla Park facilitates rapid accurate setting of the overlap of the moving knife to the stationary knife on reciprocating roller gins. This is the first time that any gage or device has been devised to aid the ginner in properly adjusting his equipment.

Research to date at Mesilla Park has not yielded a satisfactory means for keeping the roll surface and stationary knife cool on a high-capacity roller gin during ginning. However, it has been found that maintaining an even feed of cotton to the machine will reduce the temperature 50° to 100° F. This will prolong the life of the roller and thereby reduce maintenance and

down-time. The tests also showed that the use of humid air in the conventional doffing system of a modern rotary-knife roller gin would serve to control static.

F. Gin performance and cotton quality

1. Data were collected on effective gin operating time by the Stoneville Laboratory from seven commercial gins in the Mid-South area during the 1963 ginning season. Efficiencies of operating time for these gins ranged from 74.3 to 91.0 percent, with an average for the seven plants of 86.9 percent. Four of the plants studied displayed operating efficiencies of 90.0 percent or higher. Plant operating efficiencies of 90 percent cannot be obtained without excellent plant management and a gin crew in which each member pays close attention to every detail involved in his specific job. Studies were also made to determine the power and energy requirements for operating presses and trampers in cotton gins. Average energy consumption for the presses studied was 0.29 kw.-hr. per bale, with an average power requirement of 10.7 horsepower. The trampers studied used an average of 0.18 kw.-hr. per bale, with the average power requirement being 2.6 horsepower.

The engineering data collected on saw and roller gins by the Mesilla Park Laboratory shows that high-capacity gins generally have from 35 to 50 individual drive motors. The study further showed that the gins had a much higher connected load than that required to operate. This over-powering of equipment contributes to lower power efficiency and high operating cost. The ginners' power costs are higher than they should be for three reasons: (1) High installation cost because of the larger motors, wiring and control equipment; (2) under-loaded induction-type electric motors have a low power factor characteristic which results in higher current requirements than necessary, and in some instances power cost penalties are levied on low power factor demand loads; and (3) the ginner is paying for connected loads not needed for operation.

Effective operating time of gins in the Southeast was affected by the methods used for bringing cotton to the gin. Much of the cotton is delivered in one-bale lots and some in burlap sheets which are awkward and time-consuming to handle. Both practices contribute to increased total power costs because of the numerous delays. Generally speaking, the larger the lots the more efficient the operation. The Clemson Laboratory found that 51.1 to 56.6 kw. per bale was required for ginning.

2. Quality evaluation. Refinements of the seed cotton foreign matter determination test were made at Stoneville. It was found that for seed cotton cleaning and other tests where an analysis of the various types of foreign matter is important as well as the total quantity, a procedure which involves the use of three trash screens in lieu of the original two is recommended. The screens are of different size, thus the various sizes of leaf trash are separated.

Refinements were made at Stoneville of the Shirley Analyzer test procedure to give more information on the trash in lint cotton. It was found that when a 1/4-inch mesh screen was placed 1-1/8 inches from the bottom of the trash pan, the larger foreign matter particles collected on it, thus giving a separation of "large" and "small" trash in the lint. This is especially helpful in lint cleaner studies.

Formulae developed at Stoneville for calculating the moisture content of the seed cotton after 2 hours of oven drying proved to be satisfactory. There was less variation between this procedure and paired samples dried in the conventional manner.

In cooperative tests with the Crops Research Division studies were made at Stoneville of the fiber-seed separation force for four cottons (two Sp. G. Barbadense and two Sp. G. Tomentosum). It was found that Pima S-2 separated from its seeds with less force than did Pima S-1. Pima S-2 also had fewer fibers to rupture than S-1 during fiber-seed separation. The Tomentosum fiber rupture rate was greater than that for the Pimas.

Single fiber tests were made at Stoneville at weekly intervals on fiber-seed separation force and tensile strength--8,890 separate tests were made. Both tensile strength and separation force declined as field exposure increased; tensile strength declined faster than fiber-seed separation force. The percentage of fibers that ruptured instead of separating normally from the seed increased as exposure period increased. These data indicate that the ginning process will break more fibers from late-harvested cotton than from cotton harvested shortly after opening.

Studies at Mesilla Park show that the amount of moisture absorbed by various strains, species, and varieties of cotton under given conditions is not significantly different. Studies also show that alkali-centrifuge values are not affected by ginning methods but are affected by time of harvest.

At Clemson, the Shirley Analyzer was used in an effort to magnify differences in fiber properties which were caused by ginning treatments. One pass through the Shirley Analyzer did appear to increase the differences with no advantage being found for additional passes through the machine. Correlation coefficients did not increase for five passes as compared with one pass through the machine when yarn strength was correlated with fiber tensile strength and percent fibers shorter than one-half inch.

3. Effect of cultural and harvesting practices. Work at Stoneville on four varieties of cotton showed that stripping was not practical. Hand-picked lots were used as a control. All of the hand-picked cotton was classed as Middling, 1-1/32 inches. The average grade of the stripped cotton ranged from a high of 96.4 for Stripper 60-2 variety downward to 92.8 for Lankhart-57; 91.3 for Stoneville 7-A, and 89.7 for Rex Smooth Leaf. Until higher-yielding stripper cotton that will mature early and

maintain its quality can be developed, it is believed that picker harvesting will continue to dominate in the Delta area. On the sandy loam soils the present cottons cannot be produced with a stalk small enough for stripper harvesting.

Tests at Stoneville using three types of picker spindles with a hand-picked control showed that there was no important difference in the grade and staple length of the samples representing the three different spindles. The average grade of the mechanically-harvested cotton was SLM, and the hand-picked averaged Middling. The staple length of both the machine- and hand-picked was 36.1 in one-thirty second inches. A statistical analysis of the fiber and spinning data shows no significant differences in the machine- or hand-picked cotton with respect to neps, ends down, yarn appearance, fiber array length, fibers shorter than one-half inch, fibrograph length, fiber strength, or Uster strength (single strand) and imperfections. As is normal, there was a significantly lower picker and card waste associated with the hand-picked cotton. Although the statistical analysis shows significance at the 5 percent level for yarn break factor, picker and card waste and micronaire readings, all treatments fall within a close range which would not be important from a spinning mill processing standpoint.

A study of the same organization carried out by the Mesilla Park Laboratory showed only slight differences between treatments except for a significant difference in corrected spinning ends down per thousand spindle hours in favor of hand picking.

Experiments were carried out at Stoneville to determine the degree of cotton contamination by picker spindle grease and its effect on cotton quality. Lots which were harvested immediately after servicing the picker averaged 0.55 percent grease content whereas lots harvested after 3 hours contained only 0.3 percent. Generally speaking the picker and card waste was directly proportional to the grease content while the color and yarn appearance were inversely proportional.

For the second year tests were made at Stoneville on the effect of a layby chemical for late season grass control. The machine-picked wagon sample grass content of the treated field was zero as compared to 0.2 percent for the grassy field. The results of the experiments indicate that the grass encountered when not using the layby treatment (control field) has no adverse effect on harvesting efficiency or time required to harvest. When double lint cleaning is used at the gin, the grass removal from the control lots was complete enough to have no effect on the grade of the cotton. The fiber quality was the same for all treatments.

Studies of gleaning operations at Stoneville show that the net return to the farmer from gleaning operations was $87.07 per bale with six acres of gleaning required to make a bale. As compared to conventional picker spindle scrapped cotton, the gleaned material was lower in quality.

A study carried out at Stoneville showed that the range in foreign matter content in a picker basket was not significant. The tests showed that the equalizing effects of processing the cotton through the cleaning system of the gin gave the same average foreign matter distribution in the cotton at the gin stand. This resulted in essentially the same lint grades and closely comparable lint foreign matter content throughout the bale.

Tests of ginning performance and quality of two varieties in the 1961 crop and four varieties in the 1962 crop which were ginned under varying conditions at Mesilla Park were analyzed together. The data showed that Acala 1517BR-2 ginned faster than 4-42, A44, and western grown Deltapine. The BR-2 had the longest fibers by classer and laboratory measurements, and relatively small seeds with low linters percentage. All varieties, ginned at 30, 50, and 70 percent relative humidity, showed that the higher humidities are significantly better for ginning capacity and fiber length and produced fewer short fibers. Tenacity measurements had very little effect on ginning capacity among varieties, and the average tenacity for all varieties was not effected by relative humidity.

Groups of strains from three western cotton breeders were also tested. New Mexico State University included 1517D, BR-2, 6368, 8229, and 6612, the last of which was released this year as 1517V, a strain tolerant to Verticillium wilt. The 6612 had slightly better ginning capacity and turnout than did most other strains; it was bested only by the experimental strain 8229 in these two measurements. Of the Shafter, California, strains, AR-42-77, had the highest ginning capacity and turnout and of the American-Egyptian-strains, Pima S-2 with smaller seeds, led S-1 and two experimental strains in capacity and turnout.

G. Lint cleaning

1. A study was made at Stoneville of the effect of lint moisture content on trash removal and on fiber length distribution of cleaned lint. Test results showed some additional trash removal due to lint cleaning at lower moisture levels, but a more substantial quantity of trash was removed by employing a second lint cleaner at the same fiber moisture content. Upper half mean and mean length data showed some decreases in fiber length when cleaning lint at low moisture contents. However, these changes were due partially to gin stand effect.

Tests at Clemson showed that one lint cleaner would not give sufficient cleaning to prevent grade reductions because of grass. In machine-picked cotton containing a preponderance of grass, 73.3 percent of the samples were reduced one grade because of grass, 22.2 percent had a trace of grass but were not reduced, and only 2.5 percent were classed as free of grass.

H. Cottonseed handling

1. Studies of the effect of conventional gin seed handling systems conducted at Stoneville indicated that excessive handling of cottonseed will (1) lower seed germination, (2) increase physical damage to the seed coat, and (3) increase the percentage of abnormal seed. These studies will be expanded.

I. Waste collection and disposal

1. Research at Mesilla Park has led to the development of an efficient means of collecting fly lint and dust escaping from low-pressure, high-volume condenser exhaust systems in cotton gins. During Fiscal Year 1964 a pilot model inline air filter for condenser exhaust systems was designed, built, and tested at the laboratory. The filter was equipped with stainless steel bolting-grade wire cloth as the filtering media. Tests have shown this type of media to offer only small restrictions to the flow of air while maintaining high filtering efficiencies. The pilot model inline air filter performed sufficiently well in the laboratory to warrant the construction of two larger units which were field tested in a commercial gin on individual lint cleaner condenser exhausts during the 1963-64 ginning season. The field test results showed that the inline air filters could be easily installed in any system and were an efficient, economical, and trouble-free means of collecting condenser exhaust air pollutants. These test units were 99+ percent efficient in collecting fly lint and foreign matter particles larger than 165 microns and 70 percent efficient in collecting fine dust particles less than 165 microns. This produced an overall efficiency of 87 percent. These field tests, along with other laboratory tests, also enabled the formulation of concrete design procedures to assist ginners and manufacturers in the design of inline filters to meet the various conditions encountered in commercial ginning operations.

Measurements made at Stoneville show that the dust concentration inside a modern cotton gin is about the same as that of industrial districts, and the noise level is well below the level which will cause pain.

Preliminary tests at Stoneville indicate that lint fly from the exhaust of low-pressure condenser fans may be greatly reduced or eliminated by covering the condenser drum of the lint cleaner or battery condenser with a fine mesh screen wire cloth.

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## II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

### BASIC AND EXPLORATORY INVESTIGATIONS
Southern Utilization Research and Development Division, ARS

Problem. Cotton, the nation's most important fiber, is facing severe and increasing competition from synthetic fibers. Cotton is America's largest source of cash farm income and still accounts for almost two-thirds of the total U. S. mill consumption of all major fibers. However, its proportionate share of the market has been slowly decreasing as has the per capita consumption. The rapid growth of the synthetics at the expense of the natural fibers has been a phenomenon of the century. Expansion of market outlets for the chemical fibers has been based on vigorous research and development programs. The engineering and development programs of the chemical fiber industry are designed to capitalize on the special properties of each individual fiber as related to the functional use qualities desired in particular products; basically they involve the substitution of the newer fibers for cotton in cotton's traditional end use markets. Expanded research to increase the utilization potential of cotton offers the most realistic opportunity for improving cotton's competitive strength as a textile fiber and for increasing cotton consumption. Basic and exploratory investigations, studies on interrelations among fiber, yarn, and fabric properties, new and improved textile machinery, improvement of wash-wear properties and improved cotton properties and products are basic to holding existing markets or expanding the use of cotton in new applications.

Fundamental information is badly needed in applied research to help cotton gain new and maintain old markets. Fundamental knowledge of the cotton fiber as to its structure, properties, and the mechanisms involved in chemical and physical behavior serves as a basis and a guide in the design and improvement of processing machinery, mechanical and chemical processes, and in the development of new and improved cotton yarns, fabrics, finishes, and treatments. Many chemical and physical treatments, as well as textile organizations and machine designs, offer a basis for the improvement of cotton quality or lowering of processing costs. Exploratory chemical and physical research is needed to determine the true potential of such approaches prior to undertaking extensive developmental research or the construction of prototype machinery. Specific areas in which basic information is needed include the chemical properties and structure of native and modified cottons; the chemical modification of cotton cellulose; chemical reactions induced in cotton cellulose by high energy radiation; reaction mechanisms, rates, and catalysis of cotton cellulose reactions; new concepts and methods for evaluating the physical properties of native and modified cottons; relationships of the structural arrangements within cotton fibers to the physical properties of native and modified cottons; mechanisms of physical damage to cotton due to mechanical, chemical, or biological actions; fine structural changes occurring during chemical and physical modification of cotton cellulose; and correlations of the fine structure of cotton fibers with their gross behavior in textile structures.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, analytical chemists, physical chemists, physicists, microscopists, chemical engineers, statisticians, mathematicians, cotton technologists and textile technologists engaged in basic and exploratory studies to develop fundamental information needed in applied research to help cotton gain new and maintain old markets.

Basic research on the structure of cotton fiber and its relation to the behavior in mechanical and chemical treatments, essential to an understanding of the performance of fibers during processing and in textile products, is carried out at the Southern Regional Research Laboratory, New Orleans, Louisiana. Included is the research of the Plant Fibers Pioneering Research Laboratory to obtain basic information on the supermolecular structure of plant textile fibers; and to relate information of polymer and fiber structure to the mechanical and textile behavior of fibers. Additional basic research on chemical and physical properties and structure of cotton is being carried out: (1) under contract at Stanford Research Institute, South Pasadena, California, on determination of the structural components of the cotton fiber that contribute most to tensile strength and how they can be utilized to increase tensile and recovery properties; at Texas Agricultural Experiment Station, College Station, Texas, on the effect of variation in structure on cotton fiber properties caused by environmental and genetic factors; at the University of Tennessee, Knoxville, Tennessee, on investigations to determine the effects of fiber extensibility on fiber breakage in mechanical processing; at the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., on relationship of molecular size, nature, shape, conformation, and configuration of organic non-aqueous compounds to their swelling power on cotton cellulose; and at Harris Research Laboratories, Inc., Washington, D. C., on investigation of factors influencing comfort in cotton apparel fabrics; and (2) under a grant at Massachusetts Institute of Technology, Cambridge, Massachusetts, on investigation of fiber and yarn geometry in areas of deformation in cotton fabrics.

Exploratory chemical and physical research is also conducted at New Orleans, Louisiana, as a basis for the improvement of mechanical and chemical processing, and in the development of new and improved yarns, fabrics, finishes, and treatments. Additional exploratory chemical and physical investigations are being carried out: (1) under contract at General Aniline and Film corporation, New York, N. Y., on the reaction of acetylene and related compounds with cotton cellulose; at Macrosonics Corporation, Carteret, New Jersey, on treatment of cotton fibers with acoustic energy; and at Gagliardi Research Corporation, East Greenwich, Rhode Island, on chemical modification of cotton through treatments with reagents in the vapor phase; and (2) under a grant at Textile Research Institute, Princeton, New Jersey, on crosslinking of chemically modified cotton to obtain cotton fabrics with an optimum combination of resiliency and thermoplasticity.

Other research on chemical and physical properties snd structure of cotton is in progress under grants of P.L. 480 funds to the following foreign institutions: Ministry of Commerce and Industry of State of Israel, Jerusalem, Israel, for fundamental investigation of crimp in cotton fibers and its relationship to other fiber properties (project duration - 5 yrs.); National Institute of Applied Chemical Research, Paris, France, for a fundamental study of the relation of crystallinity to accessibility in cottons (project duration - 5 yrs.); Swedish Institute for Textile Research, Goteburg, Sweden, for an investigation of setting reactions in cotton fabrics (project duration - 5 yrs.); Central Laboratory, T.N.O., Delft, Holland, for a fundamental study of the response of cotton fiber structural elements to stress (project duration - 3 yrs.); Fiber Research Institute, T.N.O., Delft, Holland, for an investigation of the fundamental mechanisms and bonding forces that could be used to improve tensile strength and other physical properties of cotton textiles (project duration - 5 yrs.); Ahmedabad Textile Industry's Research Association, Navrangpura, Ahmedabad, India, for a study of the relation between fine structure and mechanical properties of cotton fibers by swelling and stretching treatments (project duration - 5 yrs.); and for a study of the physical chemistry and thermodynamics of solution and vapor phase adsorption on and in the cotton fiber (project duration - 5 yrs.); University of Bombay, Bombay, India, for an investigation of the photochemical degradation of cotton (project duration - 5 yrs.); and for an investigation of new solvents for molecular weight determination of cellulose (project duration - 3 yrs.); Indian Central Cotton Committee, Bombay, India, for investigation of the microbial decomposition of cellulose with special reference to the effect of Indian bacterial organisms on cotton and cotton fabrics (project duration - 4 yrs.); Juan de la Cierva School of Technical Investigations, Barcelona, Spain, for a study of the measurement of "total hairiness" of cotton yarn and the determination of mechanical factors contributing toward its formation (project duration - 5 yrs.); and The Cotton Silk and Man-Made Fibres Research Association, Shirley Institute, Didsbury, Manchester, England, for a study of the effect of swelling agents on the fine structure of cotton (project duration - 5 yrs.).

Exploratory chemical and physical investigations are in progress under grants of P.L. 480 funds to the following foreign institutions: Birkbeck College of University of London, London, England, for a fundamental study of the preparation and properties of phosphazene and phosphoryl chloride derivatives having potential for reaction with cotton cellulose (project duration - 4 yrs.); Indian Central Cotton Committee, Bombay, India, for an investigation of the preparation of radioresistant and radiosensitive celluloses (project duration - 5 yrs.); Ministry of Commerce and Industry of State of Israel, Jerusalem, Israel, for a fundamental study of the oxidation of cotton and crosslinked cotton by various oxidizing agents (project duration - 3 yrs.); and Chalmers University of Technology, Gothenburg, Sweden, for a basic investigation of the behavior of cotton subjected to aerodynamic forces (project duration - 3 yrs.).

The Federal in-house scientific effort devoted to research in this area totals 63.9 professional man-years. Of this number 36.6 is devoted to chemical and physical properties and structure and 27.3 to exploratory chemical and physical investigations. The domestic contract and grant research involves an additional 13.4 man-years, 8.0 being on chemical and physical properties and structure, and 5.4 on exploratory chemical and physical investigations. P.L. 480 research involves 16 grants, of which 12 are on chemical and physical properties and structure and 4 on exploratory chemical and physical investigations.

The following lines of work were terminated during the year: (1) Evaluation of the swelling behavior of cotton fibers in various environments by observation of the untwisting of single yarns (under chemical and physical properties and structure); and (2) Determination of the mechanics of nep formation in cotton during textile mechanical processing; (3) A fundamental investigation of the drying of chemically modified cotton; (4) Fundamental investigation of preparation and properties of esters, anhydrides, hydrazides, pseudohalides, fluorides, and related compounds of the phosphonitrilic chlorides for use in preparing new cotton products (P.L. 480 project); and (5) Fundamental study of the pyrolysis of cotton cellulose (P.L. 480 project), (under exploratory chemical and physical investigations).

## PROGRAM OF STATE EXPERIMENT STATIONS

Station research on cotton and cotton fiber utilization is not extensive. The Tennessee station carries out a program of research designed to evaluate cotton fiber properties for the plant breeder. In this laboratory, instruments have been developed for measuring length, fineness, maturity, tenacity, elongation, crimp, compressibility and other properties of fibers. Texas workers are evaluating the effect of seed cotton moisture content on cotton fiber quality and the effects of mechanical harvesting of cotton. Another study attempts to determine the relative usefulness of selected fiber properties and selective objective measures of quality in predicting spinning performance.

In a study directed toward development of new principles and techniques for ginning cotton, the characteristics and properties of seed cotton lint and seed which are related to basic ginning processes are being investigated. Work directed to development of new and improved engineering principles for maintaining cotton quality involves application of chemicals and other spindle moistening materials during the harvesting process and determination of effects on spinning performance.

The Arizona station is studying cross linking of cotton to produce wash and wear type of fabric and the Texas station is evaluating selected cotton wash and wear fabrics in use tests.

Four regional studies are directed to: (1) determining the relation of fiber properties to end-product performance; (2) determining the mechanism

of fabric stress absorption and performance; (3) determining properties of textile-furnishing fabrics and their importance to consumer satisfaction; and (4) determining the effects of atmospheric conditions on fabrics. Another study relates to evaluation of the effects of radiation on the physical and chemical properties of the fibers of selected fabric.

A total of 13.1 professional man-years is devoted to this research.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Chemical and Physical Properties and Structure

1. Fundamental Investigations of Adsorption and Swelling Phenomena in Native and Modified Cottons. Research to evaluate the swelling behavior of cotton fibers in various environments by observation of the untwisting of single yarns has been completed. Estimates of the relative lateral swelling of cotton fibers at room temperature in 100 different liquids were made by observation of the extent of untwisting of singles yarns during the first three minutes of immersion in the liquids. Highest values were for the known intracrystalline swelling agents; intermediate values were grouped about the value for distilled water; and values for most nonaqueous liquids were distributed exponentially from zero. In general, results of swelling evaluations by microscopical techniques agreed with ranking by the untwisting technique. Nonaqueous liquids merit more complete study. The untwisting technique provides a rapid and simple method of screening liquids with respect to their swelling characteristics; it should prove useful in screening and classifying reagents employed in the wet processing of cotton textiles. (S2 1-182).

Microscopical investigations of absorption and swelling phenomena in native, mercerized and modified cottons are in progress. Stains containing heavy metals are being explored for their possible use in the research. Ultrathin sections of raw cotton, exposed on the specimen grid of the electron microscope to solutions of phosphotungstic acid, of uranyl acetate, and of lead hydroxide, all showed heavy deposition of the metal in the primary wall area of the section when observed at a magnification of approximately 100,000 X and photographed at a magnification of approximately 50,000 X, but no quantitative interpretation was possible. Whole fibers, soaked in solutions of the stains, are being examined by cross section to evaluate extents of penetration and deposition by this approach. Based on recent and earlier experiments, it would appear that chromium and lead salts are preferable stains for following changes in the fine structure of cotton microscopically. Samples of cotton freeze-dried from various swelling agents are being compared using the electron microscope. Initial experiments have shown that freeze-drying directly from 18% sodium hydroxide solution apparently badly degrades the cotton fibers, whereas washing out the alkali prior to freeze-drying gave samples having the familiar characteristics of mercerized cotton fibers. (S2 1-209).

Research has been initiated to determine the properties and structural characteristics of cotton fibers which influence the capacity of the fibers to sorb alkaline solution, and thus to increase the usefulness of the alkali swelling centrifuge (AC) test for characterizing cottons, both native and after chemical and/or mechanical treatments. Examination of the procedural details of the AC test as applied to two cottons differing considerably in physical properties is in progress as the first investigative phase of the research. Previous work has suggested that the AC test might be a promising method to investigate swelling response of chemically treated cotton fibers and, in particular, to indicate damage to the cotton fiber primary wall. (S2 1-249, Pending).

2. Basic Studies of the Relationships of the Structural Arrangements Within Cotton Fibers to the Physical Properties of Native and Modified Cottons. Electron microscopical observations of cotton fragments treated on the specimen grid continue to reveal details of structural changes bearing on the mechanism of reactions within the cotton fiber. The effect of crosslinking on substituted cotton (investigated by dimethylol ethyleneurea treatment of acetylated, benzylated and cyanoethylated samples of different degrees of substitution) was, in general, that crosslinking increased susceptibility of lamellar fragments to hydrolytic degradation. Surface replicas of cyanoethylated cotton indicated that upon heating and stretching, normal surface rugosities are largely lost; the internal structures of highly substituted samples subsequently heated to 175° C were similar to those of unheated samples. Electron micrographs of fragments of untreated native cotton exposed on the grid to several intra-crystalline swelling agents indicated that, in thinly divided specimens, swelling by reagents of this class results in complete disruption of the fibrillar aggregates to form small discrete particles; this implies that the more easily accessible portions of the fibrillar mass are dissolved to leave the more well-ordered fractions free of any formal association one with another.

Ultrathin sections of untreated cotton samples, when prepared by the deceresol-methanol-methacrylate expansion technique, produced cross sections in which the cell wall was separated in many layers concentric about the lumen. In both slack- and tension-mercerized samples, concentricity was lost, and the expanded fiber section appeared to have a "honey-combed" structure. Samples slack- or tension-mercerized and subsequently crosslinked with formaldehyde had compact cross sections which appeared solid throughout even after application of the layer-expansion technique. Dimethylol ethyleneurea-treated samples exhibited wide variability in behavior. Postmercerization after crosslinking with formaldehyde had the effect of opening up fiber structure. When effects of postmercerization were investigated on samples crosslinked by butadiene diepoxide, no layer separation could be induced, but surprisingly, postmercerization dramatically lowered the refractive index of cottons crosslinked by this finishing agent. Observations of ultrathin sections taken from fibers treated with acrylonitrile after gamma irradiation of the cotton indicated heavy reaction in the outer layers of the fiber only. (S2 1-174).

In further research on the effect of gross and fine structure on the physical behavior of cotton fibers, a method has been developed for preventing cotton fibers from collapsing upon drying which should prove useful in studies of the fiber structure produced by controlled conditions of growth. It has been established that wetting the fibers with sucrose, potassium carbonate or potassium phosphate solutions is most satisfactory for maintaining them in the cylindrical shape as found in bolls prior to drying. Also, after several rewettings with sucrose solution and dryings, the fibrillar structure becomes more apparent. Another finding is that fiber crosslinked (as for example by treatment with formaldehyde) prior to initial drying will collapse on drying but will return to essentially cylindrical shape on rewetting with water. Work is in progress to study the relationships of fiber structure to physical behaviors employing cottons selected for unusual properties. In recent work on Asiatic cottons grown in both India and the U. S., and another group of breeder's strain cottons selected for unusually high strengths or elongations, a four-fold difference in tensile modulus and a two-fold difference in toughness were found. The largest range was found among the cottons chosen for high strengths. Differences in cellulose density were within the range found for other cottons even though wide ranges in other properties exist. The wide range in mechanical properties found among the breeders samples is evidence that cottons of widely different characteristics can be produced by breeding. Effort in future work will be concentrated on specially grown cottons with structure altered by known growth variables. (S2 1-208).

Basic research is in progress under contract at Texas Agricultural Experiment Station on the effect of variation in structure on cotton fiber properties caused by environmental and genetic factors. In this research, cottons will be grown in growth chambers under different conditions of illumination, temperature, humidity, etc. to produce samples having differences in fiber structure. The first series of cottons grown under controlled conditions (continuous light, 85° F., 70% relative humidity) have been harvested. Considerable information on differential response of varieties to controlled growth was obtained with this series of plants. Closely controlled conditions apparently cause plant growth unbalances and shedding of flowers. Mechanical difficulties with the growth chambers which caused delays in the research have now been remedied. (S2 1-217(C)).

Initial contract research at Stanford Research Institute to determine fiber components that contribute most to strength properties of cotton has involved a systematic investigation of the effects of mercerization and physical manipulations during the process on yarn strength. Yarns treated in 18% or 24% sodium hydroxide under comparable conditions had essentially identical properties but yarns treated with 10% caustic were changed very slightly and more nearly resembled unmercerized yarn. Strongest yarns were produced when the highest tensions were applied. These were least extensible. Changing the temperature at which mercerization was carried out had little effect on yarn properties. Yarns were also swollen in nine other swelling agents with measurements made of shrinkage rates and determination

of yarn strengths. Techniques will be developed for conducting electron microscope studies on surface replicas of cotton fibers and on microfibrils to formulate theory explaining the changes in tensile properties of yarn and fibers that result from swelling treatments. (S2 1-206(C)).

Fundamental studies of the role played by the structural elements of the cotton fiber in response to stress are being conducted in P.L. 480 research at the Central Laboratory, T.N.O. Through the use of modern microtechniques for manipulating and observing single fibers, a better understanding is being obtained of the internal movements that occur within the cotton fiber while it is being subjected to torsion and stretching. Fibers treated by resin treatments commonly used in wash-wear finishing of cotton have been found to be more rigid to torsion and to begin to form cracks and break at lower torsion than untreated fibers. Progress is being made in obtaining basic knowledge of cotton fibers that eventually will be directed toward efforts to improve cotton fiber properties through cotton breeding programs and improvements in cotton processing. (UR-E19-(20)-4).

In P.L. 480 research at the Swedish Institute for Textile Research, reactions which will cause setting in cotton fabrics and garments are being investigated. Treatment of cotton fabrics with solutions of certain inexpensive alkalis or inorganic salts which cause swelling of the cotton fibers has been shown to cause the relaxation of internal stresses in the fabrics. This treatment, which is generally known as "setting," decreases surface mussiness of the fabric, and in combination with standard resin treatments, results in improved wash-wear properties. In recent developments, it has been observed that the conditions under which deswelling of the fibers occur during treatment greatly influence the "setting" effect. Progress is being made toward providing the basis for reducing the amount of resin required to provide acceptable wash-wear qualities in cotton textiles. (UR-E26-(20)-2).

3. Elucidation of Mechanisms of Physical Damage to Cotton Due to Mechanical Chemical, Physical or Biological Actions. A P.L. 480 project is underway at the Technological Laboratory of the Indian Central Cotton Committee in Bombay, India, to investigate the degradation of cotton cellulose by bacteria indigenous to the Bombay area. Progress is being made in the collection and isolation of bacterial and fungal species suspected of causing damage to cotton and cotton products in this region. Cultures of cellulolytic organisms known to exist in the U. S. have been furnished to the Principal Investigator for comparative studies. Work is underway to determine the mode of attack and the mechanism of degradation of cotton cellulose by the various microorganisms isolated in the study. It is expected that the information obtained in the research will be useful in devising means to minimize or prevent microbiological damage to cotton and cotton products which is estimated to cause losses running close to a billion dollars annually to the U. S. textile industry and to users of cotton products. (UR-A7-(20)-32).

An investigation of the photochemical breakdown of cotton under different conditions of exposure to radiation is being continued in P.L. 480 research in India at the University of Bombay. It is well known that cotton fabrics are weakened by prolonged exposure to sunlight or to strong illumination. Progress is being made toward determining the mechanisms by which photosensitization and photolytic degradation of cotton and selected modified cottons take place. Basic knowledge of the reaction mechanism and kinetics is expected to be useful in devising practical means to prevent the deterioration of exposed cotton fabrics by means of chemical inhibitors or screening agents that prevent or interfere with the sequence of reactions involved (UR-A7-(20)-4).

Under a P.L. 480 grant at the University of Bombay, a study is being made of new, more stable solvent systems for cellulose in the determination of the average molecular weight of cellulose by the disperse viscosity technique. Copper complex solvent systems widely used for this purpose are extremely oxygen-sensitive, a factor which greatly complicates their preparation, storage, and use. Substantial progress is being made in studies of several iron tartrate complex solvents that are relatively insensitive to atmospheric oxygen, and in relating data obtained with them to comparable data with the older copper complex systems. Means have been developed to apply a two-component solvent system to the dissolution of high degree of polymerization cottons and mercerized samples that are difficult to dissolve in the usual solvents, thus permitting satisfactory measurement of these materials. The information obtained in this project will be useful in following the degradation of cotton by various treatments, through the application of a simpler procedure for intrinsic viscosity measurement. (UR-A7-(20)-30).

4. Investigation of the Structural and Compositional Changes Occurring During Chemical and Physical Modification of Cotton Cellulose. Work on fine structure of plant fibers has been pursued along a number of lines by the Plant Fibers Pioneering Research Laboratory. A new technique, heterogeneous reaction kinetics, has been employed in an effort to throw new light on the nature of cellulose structure. As is well-known, the rate of chemical reaction in a heterogeneous system is dependent on the structure of the system. Cellulose is generally held to be a two-phase system consisting of crystalline and noncrystalline (amorphous) fractions. These in turn are related to the microfibrillar organization of the cellulose.

In view of the strong influence, apparently, of structure and pretreatment of cellulose on reaction rates as well as observation of two consecutively differing rates of acetylation, cyanoethylation, and ester saponification, it was concluded that heterogeneous reaction kinetics of cellulose might be employed to throw considerable light on the nature of the cellulose structure and perhaps give information on its variability or uniformity in plant fibers.

The reaction of cellulose with acrylonitrile (cyanoethylation) under

alkaline conditions has been studied quite extensively during the past year, though this has been supplemented somewhat in recent months with propionic and furoic acid esterification in pyridine.

In the cyanoethylation reaction the temperature has proved to be an important factor affecting the position of the abrupt change of rate (intersection of the two rate curves) during the progress of the reaction. Reduction of the crystallinity of the cellulose by 25% brought about by ethylenediamine treatments caused a decrease in the break point in the rate curves at $50^{\circ}$ C. only from DS = 2.2 to 2.0. It was established by X-ray diffraction analysis that the break point in the rate curve is closely associated with the loss of crystalline structure of the cellulose.

While a great deal of information has thus been obtained with the cyanoethylation reaction, this has not proved to be an entirely suitable reaction. Dilution of acrylonitrile with four parts to one of pyridine, xylene, toluene, benzene, or carbon tetrachloride, which greatly reduced the rate of reaction, had very little influence on the position of intersection of the rate curves, but favored side reactions.

The most serious side reactions were those becoming prominent during the latter stages of reaction. The effects of these side reactions upon the kinetic interpretation is such as to suggest the advisability of exploring other reactions less influenced by these problems. The esterification of cellulose in propionic acid in pyridine gives considerable promise of such a reaction at the present time.

During the year a study was made of mature cotton fibers taken from unopened cotton bolls. The objective was to throw light on the controversy as to whether cotton cellulose is already crystalline in the moist state of the fibers in unopen bolls, or alternatively, crystallizes at the time the boll opens and the fibers dry out. In these studies the bolls were opened and sampled and the fibers preserved in various ways. The crystallinity of the cellulose in the undried fibers was studied by X-ray diffractometer methods. The crystallinity of portions of the fibers was compared with that of portions either dried directly or from which the water has been removed in various "indirect" ways, designed to preserve the structure existing before drying. The results lead to the conclusions that crystalline cellulose is already present in the never-dried but mature cotton fiber. However, although crystallinity was always found in the cellulose of undried fibers, the difference in crystallinity observed between directly and indirectly dried fibers leads to the conclusion that additional crystallization of the cellulose must take place during initial drying of the water-wet fiber. Crystallization evidently continues for some time after the initial drying, as indicated by the very high crystallinity of fiber which has undergone a period of storage.

When indirectly dried fiber (e.g., freeze-dried) was rewetted in water, an increase in the degree of crystallinity was observed, even above that of

fiber dried directly from the boll. The preservation of certain amounts of amorphous cellulose by the indirect drying methods (solvent-exchange, freeze-drying, drying above the critical temperature and crosslinking before drying) can be explained by assuming that additional crystallization takes place subsequently upon drying of the rewetted fiber. It was supported by observation of lower density and higher dye accessibility in samples dried by these indirect methods. The results of this study are being supplemented by studies of fibers removed from unopened cotton bolls and various earlier stages of growth from 20 days after flowering to maturity.

In continuing studies on the effect of formic acid upon the crystal lattice transformation of cellulose triacetate in highly acetylated cotton fiber it was concluded that the more concentrated formic acid solutions tended to swell or dissolve cellulose triacetate, thus promoting the polymorphic transformation.

Finally, excellent progress is being made on the effects of selected chemical modification on the structure and physical properties of cotton fiber. With the perfection of techniques for the preparation of reacted fibers it is expected that research in this area will greatly accelerate during the coming year.

In other in-house research (not in PF Pioneering Research Laboratory), investigations of improved infrared spectral techniques for the study of modified cottons to evaluate molecular structural changes produced by chemical and physical treatments have continued. Differential infrared spectra of crystalline modifications I, II, III, and IV of cellulose in which the decrystallized form of each modification was used as the reference shows that these four modifications may be distinguished by this method; conventional infrared spectra have not shown important differences. The interpretation of the differential spectra will be continued to arrive at probable frequency assignments. It also has proven possible to distinguish cottons treated with the dimethylol derivatives of methyl-, ethyl-, and isopropyl carbamates for wash-wear properties by means of the spectra of the acid hydrolyzates of these materials. Characterization of the infrared spectra associated with the complex molecular architecture of physically and chemically modified cotton cellulose is an important step in gaining insight into the structure and reactions of improved cotton textile materials. (S2 1-220).

Research was initiated to develop improved instrumental techniques for elemental analysis of additively and chemically modified cottons. Satisfactory quantitative analysis of a wide variety of cotton textile materials for the following elements by X-ray fluorescence techniques has been achieved: lead, mercury, tellurium, antimony, tin, cadmium, zirconium, bromine, selenium, zinc, copper, cobalt, iron, chromium, titanium, calcium, chlorine, sulfur, phosphorus, silicon, and aluminum. The X-ray method is generally much faster and of equal precision as the standard "wet" methods of analysis for these elements. The extension of the method to elements of lower atomic number will require radical changes in instrumental design.

In a limited number of cases, anomalous results have been obtained with the X-ray fluorescence techniques when the elemental matrix is of differing particle size. This will be investigated further. Another instrumental technique--atomic adsorption spectroscopy--appears to have definite value in the analysis of a limited number of elements, such as sodium, zinc, copper, and cadmium at the part-per-million level. A survey of the scope and limitations of these two techniques is being continued. (S2 1-218).

In further work on the separation and identification of the cleavage products of partially etherified cottons to elucidate the structure of the modified cottons, techniques for both hydrolysis and oxidation of modified cottons have been developed by which cleavage products can be prepared for identification purposes. Due to difficulties encountered in isolating stable hydrolysis products from aminoethylated cotton, emphasis was shifted to oxidation of formaldehyde treated cottons and hydrolysis of sulfone treated cottons. It has been found that samples of three types of formaldehyde treated cotton fabrics (Form W, D, and V processes) at the same level of formaldehyde content vary in rate and degree of oxidation with sodium periodate depending on method of formaldehyde treatment. Although this study did not lead to isolation of cleavage products as expected, it did result in the discovery of differences in accessibility of the three types of formaldehyde modified cottons. Electron microscopy and X-ray diffraction measurements both indicate that each of the three types of formaldehyde treated cottons are crosslinked but the Form V type is different from the others. In initial work on hydrolysis of methyl vinyl sulfone-treated fabrics, a sulfone-substituted glucose fraction has been separated from the hydrolyzate by use of gas chromotography. Known sulfone adducts of glucose have been prepared for comparison with the hydrolysis products. Elucidation of the chemical structure of the various etherified cottons will aid in the development of reactions designed to yield modified cottons having specific and controlled properties. (S2 1-214).

A fundamental investigation of the effect of swelling and stretching treatments on the fine structure and mechanical properties of cotton fibers is being conducted under a P.L. 480 grant at the Amedabad Textile Industry's Research Association (ATIRA), in India. The effect on fiber fine structure, as revealed by X-ray, microscopic and modulus measurements, of swelling fibers under tension with agents such as solutions of sodium hydroxide, ethylene diamine, and zinc chloride is under study. It has been shown in early stages of the research that orientation is much more decisive than crystallinity in determining the elastic modulus. The information obtained in the project is expected to be useful in the selection of treatments to improve the mechanical behavior of cotton products. (UR-A7-(20)-19).

In P.L. 480 research being conducted in Paris, France at the National Institute of Applied Chemical Research, a basic study of the fine structure of the cotton fiber is being made in an effort to relate the fine structure to other fiber properties that are important in the processing and use of cotton. Improved methods, both physical and chemical, have been devised for

measuring differences in the fine structure of cottons. These have been applied to a typical U. S. cotton of Deltapine variety, the fiber properties of which have been extensively studied in several laboratories, and are thoroughly known. These studies are now being extended to a series of raw, purified and chemically crosslinked cotton yarns, all spun from the same Deltapine cotton. Three commonly used crosslinking treatments, all easily measured by analytical procedures, are included in this phase of the investigation. The information obtained eventually will be translated into the development of improved cotton products. (UR-E9-(20)-61).

5. Relationship of Cotton Fiber Gross Structure to Behavior of the Fibers in Textile Structures. Fundamental investigations of the interfiber frictional force and associated fiber properties of cotton have continued. Experiments to determine the effect of drafting direction on fiber hook removal, and on processing performance, for a short staple cotton showed that the optimum draft procedure to minimize fiber hooks was not the same as previously found for a medium staple cotton. It was ascertained that the uniformity of sliver and roving was better when the "majority" hooks were drafted in the trailing position at each process. The amount of hooks entering spinning affected end breakage greater when spinning fine yarns. In experiments with a medium staple cotton, the amount of fibers (fiber mass) entering the drawing frame and removal of fiber hooks were found to be inversely related. Therefore, by using a light weight sliver (approximately 50 grains/yard) entering drawing, mills will not only obtain better uniformity but also more effective hook removal, which in turn will increase spinning performance and permit the use of higher spinning speeds. The effects of fiber hook removal and draft direction on processing performance for an extra long staple cotton is now being studied. In another phase of work, an inverse relationship between fiber bundle strength and friction was found in experiments on selected cottons differing appreciably in fiber strength. This indicates that the previously observed relationship between fiber bundle strength and drafting tenacity was not due to surface properties. (S2 1-201).

A fundamental investigation of fiber crimp, a property possibly responsible for differences in mechanical processing behavior of cotton fibers, is now in its final phases under a P.L. 480 grant at the Ministry of Commerce and Industry of the State of Israel. An optical projection system was developed to measure crimp in two perpendicular planes. The apparatus has now been improved through the development of a special curve tracer in conjunction with an electronic computer that permits the continuous and dynamic measurement of the crimp diameter, which is considered to be the main crimp parameter of cotton fibers. Crimp diameter decreased with tension for Deltapine 15 fibers. When energy required to uncrimp fibers was measured, that for Deltapine fibers remained essentially constant after the first stretching cycle. Energy for Acala 1517 fibers decreased with the first through fourth stretching cycles and increased with period of relaxation, a distinct difference in behavior of these two cottons. These improved techniques for evaluating fiber crimp are being applied to a number of cottons of differing

physical characteristics on which extensive fiber property data are available. (UR-A10-(20)-5).

B. Exploratory Chemical and Physical Investigations

1. Exploratory Chemical Modification of Cotton Cellulose. Seven classes of widely used polymers (polyvinyl esters, polyvinyl ethers, polyvinyl acetals, alkyl polyacrylates, methyl hydrogen polysiloxanes, dimethyl siloxanes, and linear polyesters) have been successfully crosslinked as coatings on cotton by rapid curing with free-radical initiators. The coatings produced are highly durable. Increased wet and dry wrinkle recovery were obtained using only moderate add-ons of crosslinked silicones (dimethyl silicone, or methyl hydrogen polysiloxane). High water repellency and fair flex abrasion resistance were obtainable in these treatments. In another phase of work, the sulfone method of wash-wear finishing of cotton has been greatly improved. High crease recovery has been obtained in very short curing times (25-35 seconds) in applying bis(hydroxyethyl)sulfone at 175-185° C. The high wrinkle resistance is achieved without excessive strength losses, and means have been found for obviating the need for an afterbleach without the lowering of crease recovery usually caused by yellowing preventatives. Emphasis in a new replacement project will be on improvement of abrasion resistance in wash-wear cottons. (S2 1-186).

Basic research is in progress on the crosslinking of various physically modified crystalline forms of cotton as a means of producing resilient cotton textiles having improved appearance and durability to wearing. The strength of crosslinked cotton was found to depend mainly on its physical state prior to crosslinking, and slightly on the crosslinking agent used. Practically unchanged breaking and tearing strength can be obtained together with high wrinkle resistance, contrary to current beliefs. This was initially accomplished by processes involving slack mercerization and restretching of cotton yarn in alkali, weaving this into fabric, scouring the fabric, and crosslinking with such wash-wear agents as formaldehyde, DMEU, APO, or bis(hydroxyethyl)sulfone. Similar results were also achieved when the scouring step in the process was omitted. Extensibility in the crosslinked special fabrics was unexpectedly high, and the degree of orientation of the cellulose crystallites was unexpectedly low, considering the recrystallizing and reorienting treatments used. The finding that strength losses once thought to be unavoidable in wash-wear finishing of cotton textiles can be eliminated is leading to evaluation of the new process by industry. (S2 1-210).

In research to develop improved methods of etherifying cotton cellulose, the catalytic effect of alkali metal iodides on the etherification of cellulose with benzyl chloride, discovered in previous work, has proven applicable to etherification with other types of organic chlorides. New cellulose ethers have been prepared using 1,3-dichloropropene, 1,4-bis(chloromethyl) benzene, 2,4-dichlorobutene, 1,4-dichloro-2-butyne, and 1,3-dichloropropane. The latter four treating agents are commercially available. The reaction of

suitably activated cotton yarn with the chloro compounds has given a high degree of cellulose substitution and crosslinking with high elongation and little strength loss. (1-Naphthyl)methyl cellulose at a degree of substitution of 0.76 showed considerable thermoplasticity, but the false-twisted yarn heat-set less readily than benzyl cellulose. In other work, a rapid and potentially inexpensive method of phosphorylating cotton has been developed with the aim of reacting this material with alcohols to form etherified cottons. The new phosphorylation method produces fabrics having higher breaking strength than those made by conventional processes such as the urea-phosphate method. (S2 1-219).

The research on exploration of cellulosic crosslinks capable of being broken and reformed at will has been terminated. Further work has shown that the reduced disulfide crosslinks in acethydrazide disulfide-treated dialdehyde cotton tend to reform spontaneously by air oxidation. The reformation of these crosslinks has also been achieved by wet state oxidation. High wet wrinkle recoveries were developed in these samples by oxidation in air-saturated water. The background information on "reversible crosslinks" from these investigations may form the basis for development of a new type of wash-and-wear finish in which creases and pleats may be introduced or relocated during fabrication or alteration of cotton garments. Investigations of spatial and structural effects of reversible and conventional crosslinks in cotton will be undertaken under a new project. (S2 1-168).

A fundamental study of reactions between epoxy compounds or their halohydrin precursors and cotton cellulose is in progress. Continued progress has been made in elucidation of the mechanisms of the cellulose-epichlorohydrin and cellulose-butadiene diepoxide reactions, which can result in both dry and wet crease resistant cottons. A comparison of these mechanisms with those involved in the reaction of cotton with halohydrin precursors of butadiene diepoxide and epichlorohydrin (principally 1,3-dichloropropanol-2, which results in cottons possessing only wet crease resistance) should make it possible to control the reactions between cotton and these compounds to produce the desired effects efficiently. Data are being obtained to explain differences in the cotton-epichlorohydrin reactions in the presence and absence of salts; and titration curves of cellulosic products resulting from reactions between alkali cellulose, epichlorohydrin, and tertiary amines have been determined and are being used to elucidate cellulose-epichlorohydrin reaction mechanisms. (S2 1-216).

The contractor (General Aniline and Film Corporation) has developed suitable methods for the vinylation of cotton yarns and fabrics by reaction with acetylene. Attempts to vinylate cotton with other reagents gave low apparent vinyl ether contents. Using acetylene, degrees of substitution as high as 0.53 have been obtained. Predominantly the vinyl ether of cellulose is formed, with some attendant formation of acetal crosslinks of the cotton as evidenced by insolubility in Cuene. Only moderate changes in textile properties have been observed to result from vinylation; however, further chemical reactions conducted at the vinyl group may lead to a variety of

interesting modified cottons with potential commercial utility. (S2 1-199(C)).

Research to gain fundamental knowledge of the influence of lead compounds on cotton, and to impart useful properties to cotton through application of new finishing agents based upon lead and other metal compounds has continued in cooperation with the International Lead and Zinc Research Organization. Preliminary evaluation of fabrics in which selected lead compounds were insolubilized within the cotton showed that, after hot water washing, special properties were imparted to the cotton. Several metals (lead, tin, copper, silver, gold, antimony, and others) have been successfully deposited on and in cotton by a reduction technique applied to certain metal salts. The treated fabrics have good rot and flame resistance, and are capable of being polished to impart a metallic sheen. Cotton fabrics impregnated with lead mercaptobenzothiazole, thiomethyl-, thiopropyl-, and thiophenyltriphenyllead have all exhibited good rot resistance. Some water repellency has been imparted to cotton fabrics by treatment with the lead compounds of N,N'didodecyldithiooxamide and stearyl mercaptan, diethyllead distearate and nickel N,N'didodecyldithiooxamide. Larger scale evaluation of some of the more promising finishes is under way. Attempts are also being made to synthesize new cellulose reactive organolead compounds. (S2 1-202, S2 1-232).

A fundamental study of the preparation and properties of phosphonitrilic and phosphoryl chloride derivatives having potential for reaction with cotton is being conducted under a P.L. 480 grant at Birkbeck College of University of London. The research is an outgrowth of work conducted under P.L. 480 project UR-E29-(20)-35, now expired, under which the chemistry of these interesting inorganic compounds was placed on a sound, systematic basis. Progress is being made in the synthesis, separation, and purification of selected compounds of this type which have configurations that suggest ability to react with cotton cellulose. The information obtained from this work is expected to furnish leads for the development of new reactive finishes for cotton textiles that will confer wash-wear, flame resistance and other desirable properties. (UR-E29-(20)-55).

2. Chemical Reactions Induced in Cotton Cellulose and Chemically Modified Cotton by High-Energy Radiation. In studies of high-energy radiation activated reactions of cotton, the radiochemical yield of graft polymerization reactions of styrene and acrylonitrile onto cotton was found to be influenced by (1) concentration of monomer in treating solution, (2) solvent, (3) ratio of monomer solution to cotton cellulose, (4) prior chemical modification of cellulose, and (5) absence of oxygen, particularly in post-irradiation reactions. The graft polymers, in the form of yarns, were thermoplastic. Yarns grafted with polymethyl methacrylate and polyvinyl acetate by a post-irradiation technique exhibited markedly increased elongation-at-break and decreased average stiffness. Cotton fabrics containing radiation-induced grafted polyacrylonitrile were found to have greatly increased flat abrasion resistance (increases as high as 2000% at 45% add-on of polymer). Radiation-sterilized surgical cotton sutures

(a commercial product) and purified fibrous cotton cellulose were demonstrated to have good post-irradiation stability, an important consideration in such processing.

Although carbohydrates generally degrade on high energy irradiation, experiments conducted on cobalt-60 gamma irradiation of sugars containing aromatic substituents indicated that these groups radiation stabilize the molecules. Work has been initiated to apply these findings to cotton. Preliminary experiments have shown that benzoylation of cotton yarn protects the cellulose from high-energy radiation as indicated by much greater retention of breaking strength in comparison to control yarns. This is the first known example of such protection of a high molecular weight carbohydrate. The discovery could have value in increasing yields of radiation-activated reactions of cellulose with minimum degradation of the fibrous cotton cellulose, and may ultimately prove applicable in the protection of cellulose from degradation by sunlight. (S2 1-176, S2 1-195).

3. Basic Investigation of Reaction Mechanisms, Rates and Catalysis of Cotton Cellulose Reactions. Dimethylol and dialkoxy derivatives of dihydroxyethyleneurea and dihydroxyethylenethiourea were prepared for a fundamental study of mechanisms of their etherification reactions with cellulose. The ring hydroxyl groups as well as the methylol hydroxyl groups of these substituted ureas have been found to react with cellulosic hydroxyls in the presence of inorganic salt catalysts, and the metal ions are complexed with the urea derivatives. The physical and chemical properties of fabrics finished with these agents have been correlated with properties of fabrics finished with equivalent concentrations of dimethylolethyleneurea in the presence of various inorganic salt catalysts at constant metal ion concentration. Data of this type are being accumulated to enable comparison of various etherifying agents as to rates of cellulose etherification reactions and to resultant fabric properties of finished products. Detailed study of the changes in fine structure of cottons finished with butadienediepoxide at room temperature under various conditions of base catalysis has shown that dry crease recovery as well as wet crease recovery can be imparted to cotton in a highly swollen state. (S2 1-196).

A recently initiated line of work is concerned with the preparation of fatty acid or hindered acid esters of cotton, and investigation of the reaction mechanisms involved. Cotton was esterified in nonaqueous media with certain monofunctional acid chlorides to produce cellulosic esters of very low degrees of substitution but with excellent dry and wet crease resistance. This shows conclusively that crosslinking with covalent bonds is not necessarily the only method of obtaining the dry and wet resiliency required in wash-wear cotton fabrics. Requisites of chain size or configuration of the acid chlorides for the imparting of crease resistance will be investigated, as will rates of esterification. (S2 1-233).

P.L. 480 research at the Shirley Institute on the pyrolysis of cotton cellulose conducted under a recently expired grant has provided information

needed for improvement of flame-resistant treatments for cotton. Reduced flammability of cotton textiles for apparel, draperies, awnings, etc., is highly desirable from the standpoint of safety. The nature of the reactions involved in the burning of cotton were studied in three different experimental systems designed to give information on what reactions occur when cotton is heated under various conditions and at different rates, and the sequence of these reactions. It was found that the first products of pyrolysis (oxygen-containing materials such as tars, carbon monoxide, etc.) require little outside oxygen for further combustion and that the degree of flame resistance of cotton fabrics is related to the char to tar ratio upon pyrolysis. This knowledge has shown that fabric finishes designed to reduce the flammability of cotton should be directed toward altering the sequences of these reactions to prevent the formation of combustible products. Certain phosphorus-containing permanent textile finishes were shown to function in this manner. (UR-E29-(20)-9).

4. Exploratory Physical Investigations on Cotton. Completed contract work at the Massachusetts Institute of Technology has shown how and why neps form in cotton. While new neps are formed during textile mechanical processing, the major portion of the increase in the number of neps is due to the breaking down of larger neps initially present in the cotton in the bales as they are received at the mills. The evidence indicates the involvement of mechanical action in every instance of nep formation. Usually, the action is one of rolling of fiber bundles during the processing operation, or the snapback of fibers suddenly released from tension or broken when their tensile yield point has been reached. There is, also, statistical evidence to show a correlation between fiber properties and nep formation. The basic information developed on nep formation will serve as a guide to breeders in developing nonnepping cotton varieties, to machine designers in developing nonnep forming machines and processes, and to machine operators in setting and adjusting their equipment to minimize the formation of neps. (S2 1-173(C)).

The experimental work in fundamental studies to ascertain the effects of chemical modification, fabric construction, and environmental conditions of temperature, relative humidity, and air velocity on the drying rate of chemically modified cotton fabrics has been completed. Processing of computer programs for analysis of the data indicate that vapor diffusion is the controlling mechanism by which water is driven off during drying. Proper drying conditions to minimize resin migration for different crosslinking reactions are predictable. Many interesting features pertaining to the effect of various chemical reagents on the surface morphology and internal structure of cotton cellulose have been determined. The research will make it possible to pinpoint those changes in process drying which are required to minimize drying costs, provide better process control, and improve product quality of various types of chemically modified cotton textiles. (S2 1-188).

Contract research has been initiated by Macrosonics Corporation on the treatment of cotton fibers with acoustic energy and the determination of the effect of such treatments on the physical properties of the fibers. Basic

information of this type is needed for the development of improved equipment for processing cotton into textiles. (S2 1-222(C)).

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## INTERRELATIONS AMONG COTTON FIBER, YARN, AND FABRIC PROPERTIES

Southern Utilization Research and Development Division, ARS

Problem. The intense competition in today's textile markets is placing increasing demands upon cotton producers and processors for high quality products tailored to meet specific use requirements. Improvement in the quality of processed products and lower costs of mechanically processing cotton into yarns and fabrics are needed to satisfy consumer demands and maintain cotton markets. For example, information is needed to determine the effect of the important fiber properties and combination of fiber properties of cottons on yarn and fabric properties and processing performance to obtain the maximum utilization potential from cottons of different fiber properties and to provide guidance for cotton breeders in developing strains having more desirable fiber properties. Improved mechanical processing methods are needed to attain maximum yarn uniformity and the resultant improvements in the general quality level and processing efficiency of all types of cotton products. New and improved methods and instruments for measuring the physical and chemical properties of cotton are needed to guide processing research in developing new and improved products.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving cotton technologists, textile technologists, textile engineers, physicists, statisticians, and mathematicians engaged in research to develop fundamental information and improved processing procedures in order to improve the quality and lower the cost of cotton products during the mechanical processing of cotton fibers into yarns and fabrics.

Research to determine the effect of fiber properties on processing efficiency and product quality is carried out at New Orleans, Louisiana. Additional research of this type is conducted under contract at Auburn Research Foundation, Inc., Auburn, Alabama, involving large-scale spinning evaluations of the effect of fiber properties and spinning variables on yarn properties and end breakage. Cooperation is maintained with cotton merchants and textile mills; the Crops Research Division, ARS, and the Cotton Division, AMS, specially on the procurement of cotton of known history with special fiber properties; and the Market Quality Research Division, ARS, to insure coordination of effort in related research. Research on development of new and improved methods and instruments for measuring the physical and chemical properties of cotton, and evaluating the processing characteristics of cotton, is carried out at New Orleans, Louisiana. Also, contract research is being conducted at Stanford Research Institute, South Pasadena, California, on development of a method for counting neps in cotton at various stages of textile processing.

Other research on effect of fiber properties on processing efficiency and product quality is in progress under grants of P. L. 480 funds to the following foreign institutions: Juan de la Cierva School of Technical Investigations, Barcelona, Spain, for an investigation of the relationship between the cohesion of cotton fibers and the properties of rovings and yarns (project duration - 4 yrs.), and for an investigation of the effect of drafting force on cotton yarn strength and uniformity (project duration - 5 yrs.); Ahmedabad Textile Industry's Research Association, Navrangpura, Ahmedabad, India, for investigation of means to minimize fiber hooked ends in cotton card and drawing slivers (project duration - 4 yrs.). Research on development of new and improved methods and instruments for measuring physical properties of cotton is in progress under a grant of P. L. 480 funds to the following institution: German Research Institute for Textile Industry, Reutlingen-Stuttgart, West Germany, for the development of an apparatus for counting neps in cotton card web (project duration - 4 yrs.).

The Federal in-house scientific effort devoted to research in this area totals 10.3 professional man-years. Of this number 9.5 is devoted to investigations of effect of fiber properties on processing efficiency and product quality and 0.8 to development of new and improved methods and instruments for measuring the physical properties of cotton. The contract research involves an additional 2.2 man-years, 1.0 being on effect of fiber properties on processing efficiency and product quality, and 1.2 on development of new and improved methods and instruments for measuring physical properties of cotton. P. L. 480 research involves 4 grants, of which 3 are on effect of fiber properties on processing efficiency and product quality and 1 on development of new and improved methods and instruments for measuring physical properties of cotton.

The following lines of work were terminated during the year: (1) Basic investigations to characterize fiber damage in mechanical processing from opening through carding to provide information needed to develop improved textile machinery and processing methods, and (2) Fundamental investigation of the causes of warp breakage in weaving of cotton yarns (P. L. 480 project), (under effect of fiber properties on processing efficiency and product quality).

## PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given on page 84)

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Effect of Fiber Properties on Processing Efficiency and Product Quality

1. Effect of Cotton Fiber Properties Such as Length, Strength, Fineness and Elongation on Fabric Properties and Processing Performance. In research to determine the simultaneous effect of pertinent fiber properties and combinations of fiber properties on yarn properties and spinning performance to

provide guides for obtaining maximum utilization of cottons of varying fiber properties, an investigation of the interrelationships of yarn number, yarn twist, and total spinning draft has been completed. The data indicate that yarn strength and elongation at break decreased linearly with increased total draft but decreased curvilinearly with increased yarn number. Also, end breakage in spinning increased curvilinearly with increased draft and yarn number, with the change in yarn number having the greater influence. The relationships found provide the spinning variable bases needed for evaluating the more than 100 samples of cottons, specially selected for their fiber properties, which have been collected for this research. The information should also be useful to mills in improving their spinning performance and product properties through systematic selection of spinning variables. Work is presently in progress to investigate the effect of break drafts, tensor settings, and total draft on end breakage and yarn properties to establish the most suitable combination(s) of draft distribution and tensor settings to use in evaluating the cottons collected. (S2 1-207).

Large-scale spinning evaluations of the effect of fiber properties and spinning variables on yarn properties and end breakage in spinning have been completed by the contractor (Auburn Research Foundation). Commercial spinning tests (25,000 spindle hours) were carried out, on three mixes or blends of cotton (representing two levels each of fiber fineness and fiber strength). Generally, the results of these tests corroborated those obtained with laboratory spinning tests (the SRRL 720 Spindle Hour Test, and the 5000 spindle hour test). Fiber strength and fineness had very little effect on processing performance and quality prior to spinning except in the case of card web neps where the coarser blend produced fewer neps. Fiber strength and fineness had no significant effect upon end breakage during spinning, yarn evenness and appearance, but did have an effect on yarn strength. It was found that fiber length distribution is more important in a blend than either Micronaire reading or fiber strength. Spinning variables such as spindle speed and twist exert a greater influence on end breakage than do fiber properties. Based on the research results, one manufacturer (the cooperator) has completely modified its blending programs, placing greater emphasis on control of fiber length distribution in the blends, and has obtained substantial improvements in processing performance (S2 1-178(C)).

The relationships between the cohesion of cotton fibers and other physical properties of fibers, rovings and yarns are being investigated at the Juan de la Cierva School of Technical Investigations under a P. L. 480 grant now nearing expiration. The cohesion of cotton fibers affects the roll settings, roll pressures and twists to be used in producing yarns of optimum quality. The main laws governing the minimum twist of cohesion of cotton rovings and yarns in connection with testing conditions (length and tension) and fiber parameters (length and micronaire) and yarn parameters (number of fibers per cross section and twist) have been determined; an improved apparatus for measuring minimum twist of cohesion has been developed; and trial work is underway to establish the relationship between fiber surface properties and minimum twist of cohesion. Information developed in this project should permit the relatively rapid and simple measurement of force of cohesion to be

used in predicting the spinning efficiency and yarn properties of cottons of differing fiber properties. (UR-E25-(20)-2).

2. Improved Processing Procedures to Obtain Maximum Utilization of Native and Modified Cottons. The research project to develop optimum processing procedures to minimize the detrimental effect of short fibers on cotton spinning performance and product quality has been terminated. Spinning evaluations of 16 lots of California cottons using the SRRL 720 Spindle Hour Test confirmed previous findings on Arizona cottons that the adverse effects of inferior fiber length distributions on spinning performance can be mitigated by the selection of optimum yarn twists and spinning drafts. Decreasing spinning draft and increasing yarn twist substantially reduces end breakage rates on cottons of inferior length distributions (high short fiber content). The influence of draft is more pronounced on these cottons than on superior cottons. The research findings concerning the relationships between fiber length distributions and spinning variables will enable spinners to select the proper combinations of spinning variables required for optimal spinning performance of cottons having inferior fiber length distributions. (S2 1-179).

Research has been initiated to study principles and procedures for optimum blending of cottons of varying fiber properties. In exploratory processing experiments on two 50/50 mixes of coarse and fine fibered cottons (one with minimum blending; one with maximum) it was found that, while the average finenesses of the fibers in the rovings were equal, the homogeneity (based on variability of fineness along the rovings) of the roving having minimum blending was superior. There were fewer imperfections (as measured by the Neptel instrument) in those yarns processed from the stock having minimum blending. Preliminary indications are that, in processing a blend of fibers differing widely in fineness, preferential feeding may exist and the more machines used in opening and picking, the less the degree of blending obtained. Subsequently, the processing experiments were extended to 50/50 mixes (one with minimum blending; one with maximum blending) of two cottons having wide differences in fiber length distribution (short fiber content), in comparison with similar mixes of a coarse and a fine fibered cotton. Maximum blending produced yarn having skein strength much superior to yarns resulting from minimum blending. Yarn strengths were inversely related to yarn strength variability and to yarn number variability. These results indicate that yarn strength, skein as well as single strand, is a better reflector of insufficient mixing than is fiber bundle tenacity or yarn uniformity as measured by the Uster Evenness Tester. For poorly mixed stock, differences in fineness produced greater differences in processing performance than did differences in fiber length distribution; however, for well mixed stock, processing performance was about equal. (S2 1-234).

The research to characterize fiber damage in mechanical processing of cotton from opening through carding to provide information needed for developing improved textile machinery and processing methods has been terminated. In the carding process, variation in speeds of lickerin, flats, or production caused no significant changes in either fiber lengths or alkali swelling centrifuge (AC) values, but some very slight differences were noted in

spinning performance. Samples from within the running card showed negligible AC value changes after passage through the actual carding area--whether flats or granular surface--but the cylinder-to-cylinder transfers produced measurable increases. Microscopical examination of fibers from card webs after passage through the crush roll attachment of the card showed no unusually damaged areas in the fibers, but fibers which had been subjected to 30 tons per square inch of static pressure in a hydraulic press exhibited excessive damage--bruises, mashing, fractures--extending deeply into the secondary wall. Comparison of important fiber properties of a pair of Deltapine-15 cottons (one harshly ginned and the other normally ginned) after a range of picker-beater actions showed that wide variation in ginning treatment produced no recognizable differences in effects on these properties. These findings are in agreement with results of earlier laboratory studies of fiber damage using the Nepotometer. (S2 1-185).

In the spinning of cotton yarns, assemblies of fibers are simultaneously drawn out and twisted. The drafting forces exerted during the spinning operation affect the quality of the resulting cotton yarns. Research is nearing completion under a P.L. 480 grant soon to expire at the Juan de la Cierva School of Technical Investigations in which an investigation has been made of the effect of various factors in spinning, such as drafting speed, roving twist, apron opening, roll setting, etc., on drafting force in the drafting zones of high draft spinning equipment, and how the drafting forces affect yarn quality. Means have been developed to actually measure the drafting forces in the front and rear drafting zones. Results obtained in the investigations indicate that lowering roving twist and increasing drafting speed increases yarn strength, which means that mills may be able to increase their spinning production with an improvement in yarn strength by this means. The investigation has provided basic information that will be of assistance in developing improved drafting systems, and in making more efficient use of existing systems. (UR-E25-(20)-13).

B. Development of New and Improved Methods and Instruments for Measuring the Physical and Chemical Properties of Cotton

1. Development and Adaptation of Instrumental Techniques for Measuring the Changes Imparted to Cotton by Chemical and Mechanical Processes. Further research was conducted to develop reliable test methods to properly evaluate cotton stretch yarns and fabrics. Three test methods (a static load test, a static extension test, and an extension-cycle test) were evaluated for determining stretch and recovery properties of slack mercerized, resin-treated fabrics. The static load test requires the least time and is also the least complicated of the three. It has been found that by selecting certain conditions of load and time the static load test will give values of growth nearly the same as those obtained with the static extension test. The extension-cycle test will usually rank fabrics according to the amount of growth in the opposite order to that obtained by the other two methods. In testing falsetwisted or backtwisted cotton stretch yarns, the previously developed test procedure for multiple strand specimens has been modified so

that different size yarns can be tested on a comparable basis (a pretension of 0.0006 g./denier and a cycle load of 0.024 g./denier). The test methods developed thus far have proven very useful in evaluating various stretch products from the cotton research program and in guiding research to produce cotton stretch products with improved properties. (S2 1-212).

Neps, small tangled clumps of fibers that first become visible in the card web from the cotton carding machine, are the cause of serious irregularities or defects in cotton fabrics. The counting of neps in the card web is a necessary quality control measure in the production of fabrics, but it is difficult and time consuming when done by the manual methods usually employed. Research under a recently completed P.L. 480 project at the Juan de la Cierva School of Technical Investigations has led to the development of a rapid, automatic scanning device by means of which neps are counted by measurement of irregularities in the transparency of card web samples. This device has been combined with an electronic integrating instrument which will classify the measured neps and irregularities into four groups according to size, and automatically record the number of irregularities in each size group in a given sample of card web. The institution is continuing the development through its own program to find means for distinguishing neps from other irregularities in the card web, thus permitting the counting and classification of neps as distinguished from trash particles. (UR-E25-(20)-1).

P.L. 480 research is continuing at the German Research Institute for Textile Industry to develop an apparatus for the rapid and automatic counting of neps in cotton card web by means of light reflectance and detection. Further progress has been made toward the development of an instrument capable of automatically and continuously measuring and recording neps in the web from a full scale card, based on a prototype developed for use with a laboratory scale card. The development, if successful, is expected to be of great value to cotton processors since it would provide rapid means for following, and perhaps automatically controlling, an important processing variable that affects cotton fabric quality. (UR-E10-(20)-2).

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1/ Publication resulting from research under grant of P.L. 480 funds to the foreign institution.

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1/ Publication resulting from research under grant of P.L. 480 funds to the foreign institution.

Development of New and Improved Methods and Instruments for Measuring the Physical and Chemical Properties of Cotton

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1/ Publication resulting from research under grant of P.L. 480 funds to the foreign institution.

## NEW AND IMPROVED TEXTILE MACHINERY
Southern Utilization Research and Development Division, ARS

Problem. Cotton is plagued by problems of trash and nonuniformity of fiber length distribution that are not present in synthetic fibers, paper, and other competitive products. Highly efficient methods of cleaning are needed by the cotton textile industry to process satisfactorily the large quantities of machine-harvested and roughly hand-harvested cottons being marketed. Last year 71% of the cotton crop was harvested by these methods in the United States. Such cottons are difficult to clean with existing textile equipment because of the type of their trash -- largely fine, leaf trash. The development of an integrated system for opening, cleaning, and carding today's cotton can provide substantial improvements in quality and lower costs. The present cotton mill utilizes ten or more processing stages and, compared with other manufacturing systems, an excessive amount of labor. The redesign of existing equipment and the development of radically new types of processing machinery offers an opportunity for major improvements in uniformity and overall quality of textile products, and for savings in manufacturing costs through decreased waste of spinnable fiber, and through reduction in machinery investment, space, and labor.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving mechanical engineers, physicists, and cotton technologists engaged in research to design and develop new and improved equipment for processing cotton into higher quality, lower cost consumer products.

Research to develop improved mechanical processing machinery, for opening through carding, is conducted at New Orleans, Louisiana. This work includes the development of experimental machines and pilot scale machines for evaluation under pilot-plant conditions, and subsequent development of plans for scaling up successful units into practical, commercial size equipment. Current research involves the development of a bale-breaker blender for opening and blending cotton, the improvement of cleaning at the card, and the development of a machine for removing short fibers from cotton. Close cooperation is maintained with cotton textile machine manufacturers and cotton textile processors in the establishment and dissemination of engineering specifications for the commercialization of new and modified processing equipment. Additional research in this area is being conducted under contract at General Applied Science Laboratories, Inc., Westbury, L. I., N. Y., on the aerodynamic separation of lint cotton into individualized fibers to provide information needed for improving cotton textile processing equipment.

The Federal in-house scientific effort devoted to research in this area totals16.4 professional man-years. All of this effort is on the development

of improved mechanical processing machinery - opening through carding. The contract research involves an additional 1.1 man-years, in the field of improved mechanical processing machinery-opening through carding.

## PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given on page 84)

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Improved Mechanical Processing Machinery - Opening Through Carding

1. Equipment for Blending Cottons of Different Fiber Properties to Produce Improved Cotton Textiles. Further research on the pilot model, of half-size, bale-breaker blender for opening and blending cotton has culminated in the development of a prototype machine capable of opening and blending a "sandwich" or composite bale consisting of as many as fifteen or more layers from different bales of cotton, at an equivalent production rate of a bale an hour in a full size machine. It has not proven possible to operate the pilot machine efficiently at production rates much higher than this. A mechanical sandwich-bale compression system incorporated into the prototype machine to enable processing more cotton per loading was found to be unsatisfactory from an operational and economic standpoint and has been abandoned.

Work is now being initiated under a new project to scale-up and modify the design of the pilot model blender into a full size machine, and to evaluate this machine under laboratory and mill conditions. Several modifications of the pilot blender will be tested prior to undertaking final design of the new full size machine. (S2 1-154, S2 1-252).

2. Improved Cotton Carding Machinery for Better Cleaning, Fiber Separation and Orientation. Research directed toward the improvement of cleaning at the cotton card has continued. An improved method of feeding the card is needed to overcome existing limitations in trash removal and fiber separation. A Precarding Feed System has been designed, constructed, and installed. All mechanisms are operating satisfactorily. The doffer-transfer cylinder appears to perform best at relatively high speed. The precarding mechanism is undergoing evaluation as an individual machine, i.e., separate from the card, to enable evaluation of the quality of web and sliver as a sensitive indicator of effects achieved by changes made in the mechanism.

Additional investigations of a conventional card feed system have shown that its efficiency is independent of speed and production rate when the relative motion of all units is maintained. There was no loss in cleaning and web quality with speeds and output increased to over twice normal. Basic studies established that when the normal positive air pressure (about 1/16 inch water) existing above the feed point of the card is lowered to zero by an external source of suction, the efficiency of the machine is improved.

Trash removal is increased and loss of spinnable fibers is decreased. Lowering the pressure into the negative range of 0 to -1 inch water is detrimental.

Another phase of work involves development of a suitable mechanism for drafting picker laps for feeding the card. An experimental lap-drafting apparatus utilizing conventional drafting rolls proved unsuitable. Therefore, a completely new type drafting apparatus was designed and a bench model constructed. Design and operational variables are presently under investigation. Initial results indicate that the new approach has promise for improving the quality of products from the cotton card, and the quality of cotton yarns. (S2 1-215).

3. Machine for Removing Short Fibers from Cotton. Research was continued on the application of uniform and nonuniform electrostatic field fractionating devices to the problem of removing short fibers from cotton. Means for feeding individualized fibers to the devices at higher rates have been developed to increase production. The increased quantities of individualized fibers can now be supplied to a point where degradation in the quality of electrostatic fractionation occurs, due largely to the interference of air currents generated by the feed system. Numerous modifications of the fractionating devices have been investigated in attempts to increase production rates to a reasonable level while maintaining high percentage short fiber removal. In all instances increasing the production resulted in a rapid decrease in fiber fractionation. A high speed photographic study is being conducted to determine if a relationship exists between fiber length and electrostatic attraction. Such a relationship will be helpful in designing more efficient electrostatic fractionating devices. Use of mechanical forces to fractionate fibers is also under study. An apparatus combining aerodynamics with mechanics was designed, constructed, and will now be evaluated. (S2 1-164(Rev.)).

4. Aerodynamic System for Separating Lint Cotton into Individualized Fibers. An analytical investigation of the application of aerodynamic forces for individualizing cotton fibers is being conducted in contract research at General Applied Science Laboratories, Inc. The contractor has made a theoretical study of the flow of fibers in a viscous fluid (air) as the first phase of the investigation. A system of equations has been derived for predicting particle motion in air. In this study, the particle was assumed to be an elongated ellipsoid of revolution to approximate the geometry of a cotton fiber. The results of this analysis provide information on the aerodynamic force characteristics of the fiber and are to be used in the study of fiber motion in nonuniform flows. A series of experiments was also conducted to study whether substantial fiber separation could be accomplished by rapidly accelerating a tuft through an orifice. Data obtained with existing equipment over a range of pressures will be utilized in designing a new apparatus for achieving improved fiber separation. If a satisfactory system for individualizing cotton fibers can be devised, this would enable the scientific design of a single machine for opening, and

possibly cleaning, lint cotton to process cotton more efficiently into higher quality textiles at lower cost. (S2 1-204(C)).

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### Improved Mechanical Processing Machinery -- Opening through Carding

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## IMPROVEMENT OF COTTON WASH-WEAR PROPERTIES
Southern Utilization Research and Development Division, ARS

Problem. Garments which are wrinkle resistant and suitable for wash-wear use are increasingly important to the consumer. Although much progress has been made toward securing this market for cotton, much additional information is needed to hold and expand cotton's share of this enormous market. According to current industry estimates 1.2 million bales of cotton are used annually which would not have been utilized except for the wash-wear development. Projected estimates indicate that in the future most apparel and almost all household textiles will be given a wash-wear or a minimum-care finish. Research on synthetic fabrics is mainly aimed at this lucrative market and is several times greater than the entire utilization effort on cotton. At the same time chemical firms are reducing their research in the development of cotton wash-wear finishes. Promotional advertising claims on cotton wash-wear products have exceeded the actual achievement, and many problems remain to be solved. Much fundamental information is needed to explain mechanisms of the reaction of cotton with crosslinking agents as a basis for the development of new and better wash-wear finishes and for the improvement of present processing techniques. Much applied information is needed which, while essential to the maximum utilization of cotton, is generally beneficial to all processors and therefore comparatively unattractive financially to individual companies. Areas in which research is needed to improve wash-wear cottons include processing techniques, fabric appearance, durability, and comfort. Fabric appearance involves the ability to dry smoothly, resistance to wrinkling or mussing during wear, resistance to dry, wet, and oil soiling, introduction of durable creases as desired, dimensional stability and elimination of seam pucker. Durability involves tensile and tearing strength and abrasion resistance in the finished fabric as well as resistance to abusive laundering, particularly bleaching and souring. Comfort involves moisture absorption during use, elimination of odor on storage or wearing and, in certain cases, stretchability of fabric.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, physical chemists, analytical chemists, physicists, microscopists, chemical engineers, mathematicians, cotton technologists, textile technologists and textile engineers engaged in both basic and applied research on wash-wear finishing and improvement of wash-wear properties of cotton. Informal cooperation is maintained with textile finishers, chemical manufacturers, and textile research institutes in connection with the research.

Basic and exploratory research on wash-wear finishing of cotton is conducted at New Orleans, Louisiana. This research is designed to give a better understanding of the chemical reactions and physical changes taking place in wash-wear finishing and the crosslinking of cotton in general. It also

seeks to correlate the properties of the finished cotton with the nature of the crosslinking agent. Basic studies of the relationship of fiber properties to fabric behavior in wash-wear treatments are also conducted. The results provide a broad and sound foundation for the development of new practical wash-wear finishes for cotton. Research on the improvement of smooth drying properties -- the essential features of a wash-wear fabric -- is conducted at New Orleans, Louisiana. Some important phases of current work involve development of new crosslinking treatments and optimum wash-wear fabric structures; combination of chemical and mechanical treatments to improve strength and resilience; and pilot-plant evaluation of promising laboratory finishes. Additional research on improved smooth drying properties is in progress under contract at the Fabric Research Laboratories, Dedham, Massachusetts, on investigation of the relationships between fabric structure and ease-of-care performance; and at North Carolina State College, Raleigh, North Carolina, on the effects of mechanical treatments of fabrics prior to, during and following resin finishing on ease-of-care properties.

Research to develop new and improved processing methods for the production of wash-wear cotton yard goods and garments is carried out at New Orleans, Louisiana. Processing methods are being investigated for the production of wash-wear cotton stretch fabrics with improved strength, drape and hand. Methods of crosslinking stretch cotton to stabilize the fabric and make the stretch durable to laundering are undergoing study. Cost estimates for new chemicals and for processing of cotton are made to aid industrial establishment of the research developments. Additional processing research is being conducted under contract at Georgia Tech Research Institute, Atlanta, Georgia, to develop improved cotton sewing thread for wash-wear fabric structures, compatible with existing high-speed manufacturing methods, which will not cause seam pucker, or which will have a markedly reduced tendency to cause seam pucker.

The Federal in-house scientific effort devoted to research in this area totals 29.1 professional man-years. Of this number 8.4 is devoted to basic and exploratory research on wash-wear, 15.4 to research on improved smooth drying properties, and 5.3 to new and improved processing methods. The contract research involves an additional 2.9 man-years, 1.7 being on improved smooth drying properties, and 1.2 on new and improved processing methods.

## PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given on page 84)

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Basic and Exploratory Research on Wash-Wear

1. Basic Studies of Recovery from Wrinkling and Creasing. Several lines of investigation of wet and dry crease recovery mechanisms in wash-wear cotton

products have continued. In physical behavior studies, the immediate tensile recovery (first few seconds) has been found to be the most informative tensile measure to differentiate wash-wear treatments and mechanisms of recovery. It is the most sensitive to test conditions and modifications and the most improved when achieving wash-wear properties. The tensile recoveries of mercerized, formaldehyde-treated cotton yarns indicate that slack mercerization decreases permanent set and increases delayed recovery. The increase in delayed recovery, greater under wet than under standard conditions, is achieved by decreases in immediate recovery. In extending the work to fabrics (cotton printcloth treated by several formaldehyde crosslinking methods), it was found that recovery differences due to testing humidity and treatment are twice as large when measured on the yarns as on fabrics. The tensile recoveries have shown differences between wash-wear treatments which could not be observed from crease recovery and could offer explanation for differences between crease recovery and performance in many fabrics. Density values of the cottons were found to decrease with increasing chemical crosslinking and with increasing water content of the formaldehyde treating solutions.

Electron microscopy investigations have shown that structural members of the cotton fiber can be immobilized by crosslinking and the fiber rendered unresponsive to cellulose swelling and dispersing agents. Application of a technique, developed for separation of the cell wall lamellae in the cotton fiber, demonstrated that inter-lamellar and intra-lamellar crosslinking are correlated with the chemical history and physical behavior of the fiber. Inter-lamellar crosslinking is usually associated with high dry-crease recovery; less inter-lamellar bonding in crosslinked cotton usually corresponds to higher wet- and lower dry-crease recovery.

In other work it was established that the use of additives to preserve swelling in dry-cure crosslinking raises moisture regain but not water-of-imbibition, while wet crosslinking with increasing swelling raises both. This indicates that there are at least two separate mechanisms involved in the general term swelling, and points to the possibility that desirable properties of cotton can be increased without undesirable side effects by use of specific changes in absorption swelling. The use of additives in dry-cure crosslinking processes has practical possibilities. (S2 1-189; S2 1-262, Pending).

Recent research on relationships of fiber properties to fabric behavior in wash-wear treatments has involved investigations of the correlation of wrinkle recovery and elastic recovery for various types and structures of wash-wear fabrics. A higher correlation of wrinkle recovery to elastic recovery was found for printcloth than for basket weave, and for high twist than low twist in yarns, when elastic recovery was measured at 4% strain. When fabrics are grouped according to their modulus into low, medium, and high, the correlations improve more for the basket weave than the print. Since the printcloths are the more rigid fabrics, the effects of rigidity possibly affect the relationships. The previously reported inverse

relationship between resin add-on and density for crosslinked cottons was found not to be affected by yarn twist but it is affected by fabric weave. A loose weave fabric is reduced more in density, at a given add-on, than a tight weave fabric. Tension during resin treatment reduces density in the case of prescoured fabrics, but increases it in the case of slack premercerized fabrics. The inverse relationship between density of resin treated fabrics and Monsanto Wrinkle Recovery is affected by cloth type, pretreatment, extent of resin treatment, and tension applied during treatment. Progress in understanding the complex relationships in translation of fiber properties to such fabric properties as wrinkle recovery, bending rigidity and strength in fabrics of different structures, and the effects of the variables in resin treatments on fiber and fabric properties, will aid attempts to alter fiber properties by chemical and physical methods to achieve improved wash-wear fabric properties. (S2 1-198).

Initial findings concerning the effects of time and environmental conditions on the rate of wrinkle recovery of wash-wear cotton textiles were confirmed when the studies were extended to numerous types of crosslinking agents. Differences in rate of recovery due to finishing agent used are most pronounced in the first 10 seconds of the test. Recoveries after 10 seconds, and especially after one minute, appear to be an effect of the level of treatment instead of the type of finishing agent. It appears that for the highest level of wrinkle resistance, agents imparting high immediate crease recovery are most desirable. Tests conducted at different relative humidities showed that the recovery angles at 45% and 65% R.H. are generally higher than at 30% R.H. APO finished cotton seems to be unique in that it shows a maximum recovery angle when creased at about 90% R.H. and allowed to recover at 65% R.H. In contrast, cotton finished with dimethylol ethyl triazone or urea formaldehyde appears to exhibit this maximum when creased and recovered at 65% relative humidity. Wet crease recovery angles of fabrics finished with these three crosslinking agents are lower than those determined under the atmosphere of the standard test conditions. As moisture content of wetted APO finished cotton is increased, the recovery angle is decreased. Since crease recovery properties of wrinkle resistant cottons depend upon atmospheric humidity and moisture content of the fabric, and these recovery properties are different for various finishes, it is possible that a specific finish may be more suitable for use in a particular climate or geographical area. (S2 1-203).

B. Improved Smooth Drying Properties

1. Development of Treatments to Improve Strength, Resilience and Other Desirable Properties of Wash-Wear Cottons. Research has been initiated under a new project to produce wash-wear cotton fabric with improved smooth drying properties, wet crease recovery, and moisture absorptivity by using treatments that swell the cotton before or during crosslinking. Inert inorganic salts have been used in dry-cure crosslinking to improve moisture regain and swellability in the treated cotton fabric; these salts can also increase reactivity in wet crosslinking treatments. The inorganic additives

are less expensive and more attractive for commercial use than the organic additives previously reported, and will be investigated further. Swelling treatments such as mercerization give greater swellability in crosslinked cotton if water washing and evaporation of water are avoided. Swelling by acids and salts is ineffective if water washes are used. (S2 1-235).

The production of excellent smooth drying and wrinkle resistant fabrics by crosslinking cotton with highly reactive methylolamide amino acid derivatives is being sought in recently initiated research. Four poly 2-carbamolylethyl derivatives of amino acids (glycine, alpha alanine, beta alanine and lysine) have been prepared, methylolated, and used to produce wash-wear cottons. These agents have proven to be highly reactive to cotton but, in general, are slightly susceptible to chlorine damage. Major effort has been on the glycine and alpha alanine derivatives, which can be isolated and purified. The lysine agent has been blended with some success with urea-formaldehyde and formamide-formaldehyde adducts. Synthesis of similar agents with phosphorus acid groups has been unsuccessful thus far.

Several formaldehyde-free, N-methylol crosslinking agents have also been prepared. Succinimide, N-methyl formamide, and 2-pyrolidone add to glyoxal to form compounds with no NH groups. N,N'-dihydroxyethylene-bis(2-pyrolidone) offers the most promise of these agents. Use of formaldehyde-free agents of this type could eliminate odor problems and also reduce costs of wash-wear finishing by elimination of the afterwash. (S2 1-227).

Research is in progress to determine optimum conditions for the application to cotton of dimethylol monoalkyl carbamates to produce durable wash-wear finishes. The effects of changing the reaction conditions--time, temperature, reagent ratios, pH, nature of the alkyl substituent, presence of N-substituents--in the methylolation of monoalkyl carbamates have been established. This fundamental information should be of much practical value by providing the best routes to the production of the carbamate crosslinking agents. Finishes from three of the methylolated products have exhibited outstanding durability to repeated commercial laundering under rigorous conditions of hot alkaline washing, chlorine bleaching, and acid souring. A citric acid-magnesium chloride mixed catalyst system has proven effective for carbamate finishing at relatively low (120° C.) curing temperatures, as well as at conventional curing temperatures (160° C.) for very short times (30 sec.). Preliminary toxicity tests conducted by the Pharmacology Laboratory, WU, using rabbits as the test animal, indicated no evidence of skin irritation from carbamate-finished cotton. Interest by industry in carbamate finishes continues to grow. Several companies are now offering dimethylol alkyl carbamate finishing agents on a commercial basis. (S2 1-230).

Contract research at North Carolina State College to determine the effects of mechanical treatment of cotton fabrics prior to, during, and following resin finishing on the ease-of-care properties of the fabrics is progressing satisfactorily. The effectiveness of DMEU resin on wash-wear rating was found to be reduced by 10 commercial launderings but not equally for fabrics

subjected to the different stretching and compressive shrinkage processes. The reliability of these observed differences will be more accurately assessed after other type crosslinking treatments are evaluated. Physical tests have been completed on all APO resin-treated fabrics, and statistical evaluation of the data in relation to treatment variables is currently in progress. Progress is also being made in treating the various fabrics with the ethyl carbamate finishing agent. (S2 1-183(C)).

2. Development of Optimum Wash-Wear Fabric Structures. The research project to develop optimal structures for cotton fabrics for wash-wear products has been terminated. The research has confirmed the findings of others that fabric structure plays no important part in improving the smooth drying properties of a fabric, but does improve such physical properties as strength (tear in particular) and abrasion resistance. However, improvements due to structure in the basic, unfinished fabric are in a large measure nullified on finishing and crosslinking. Two methods for providing "built-in" stress relief within the fabric structure (via additional yarn length between cross-yarn contacts) were investigated: (1) a chemical method (slack mercerizing an open weave fabric), and (2) a physical method (weaving in the additional yarn length at the loom). The "built-in" stress relief approach failed to give the improvement in wash-wear properties expected on a theoretical basis. This may have been due to the inability to crosslink and cure the test fabrics in a smooth state under tensionless conditions. (S2 1-163).

Analyses of data obtained in the contract research at Fabric Research Laboratories on relationships between ease-of-care performance and geometry (structure) of cotton fabrics have been completed. The research has shown that wrinkle recovery measurements can give a reasonable guide to wash-wear behavior. They are less applicable when marked changes in fabric stiffness occur. If flexural rigidity is increased, the wash-wear rating for any given level of wrinkle recovery is apt to increase. The testing atmospheric condition which showed the best relation between wrinkle recovery and wash-wear behavior was 120° F., 15% relative humidity. Ease-of-care characteristics achievable by structure differences were found to be small in the case of fabrics not tightly woven. In dense fabrics, advantages are to be gained from weaves of long floats to increase yarn mobility. In both open and closed weave fabrics, increases in yarn mobility resulted in increased tearing strength. Mercerization increased both tearing strength and wrinkle recovery characteristics. (S2 1-170(C)).

C. New and Improved Processing Methods

1. Wash-Wear Cotton Stretch Fabrics With Improved Strength, Drape and Hand. Good progress has been made in research investigations of finishing treatments to produce wash-wear cotton stretch fabrics with improved strength, drape and hand. Restretching slack mercerized cotton fabrics to original dimensions, then crosslinking, has yielded fabrics with much greater breaking and tearing strength than the crosslinked control fabrics. The effect that yarn and fabric structure have on the improved strength achieved by the

restretching process is being investigated. The most significant changes due to yarn structure and mercerization have occurred in the filling properties. For textile structures studied to date, twist multiplier had little effect on warp breaking strength properties whether the fabric was or was not mercerized before crosslinking.

It has been found that drapability of slack mercerized printcloth is slightly improved by use of polyethylene softener, but the improvements due to crosslinking with gaseous formaldehyde are greater. Variables in gaseous treatments for producing improved wash-wear and strength properties are being determined. Dimethylol ethyl carbamate treated fabric, cured with gaseous catalyst, has good wrinkle resistance, strength, and resistance to chlorine damage.

The discovery that swelling of the cotton fibers can be increased by diluting the caustic in the impregnated fibers after the mercerization treatment will be investigated from the standpoint of establishing optimum conditions for restretching to improve strength properties of the finished fabric. Wet crease recovery improvement of fabric has been achieved by carboxymethylation in conjunction with slack mercerization; modifications of this technique will also be studied. (S2 1-211).

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## COTTON PRODUCTS WITH SPECIAL PROPERTIES
Southern Utilization Research and Development Division, ARS

Problem. In many uses where special properties are of paramount importance, cotton is being replaced by synthetic materials. To improve its position in the textile market, which has declined from 79.5% of mill consumption of all textile fibers in 1939 to an estimated 56% in 1963, new applications must be explored and improved products developed to meet the competition of synthetic fibers. Cottons having high recoverable stretch, durable loft, light-weight bulk, pleasing textures, warmth and other highly desirable properties are needed to enable cotton to compete successfully with synthetic fibers in the rapidly expanding market for stretch and bulked type fabrics. Fabrics designed to achieve increased resistance to tearing and abrasion, flex life and other strength properties are needed to improve the wear life of cotton textiles for apparel, household and industrial uses. Cotton fabrics must be designed to withstand better the elements of weather and finishes developed that will provide greater protection from solar radiation, microorganisms, acids and fire, and that will resist color change. Additional basic information must be developed to improve cotton's resistance to water and oil-borne soils, and to dry soiling. Resistance to soiling ranks fifth in importance among the 40 end-use qualities for textiles. Cheaper and durable flame retardant finishes for cotton, specially for outdoor use, are needed. Numerous consumer preference surveys have shown that a great potential demand exists for cotton material that will be more lustrous without sacrifice of functional properties. Cotton textiles with multipurpose finishes are also needed, particularly those where several desirable end-use properties can be introduced in a single process.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, analytical chemists, physical chemists, physicists, microscopists, chemical engineers, cotton technologists, textile technologists and textile engineers engaged in both basic and applied research to develop new or improved cotton products possessing special properties to meet the competition of synthetic fibers and other synthetic materials in various end uses. Informal cooperation is maintained with textile finishers, chemical manufacturers, and textile research institutes in connection with the research.

Research is carried out at New Orleans, Louisiana, in cooperation with the Foundation for Cotton Research and Education (affiliated with the National Cotton Council of America) and the Canvas Products Association International, to develop cotton fabrics with improved resistance to outdoor weathering. This research includes discovery of new and more effective biocides, and sunlight-resistant pigments for cotton textiles; and development of improved formulations, equipment and procedures for producing weather resistant cotton textiles. Additional research is being conducted under contract

at Texas Woman's University, Denton, Texas, on development of weather-resistant, water-repellent finishes for cotton; and at Southern Research Institute, Birmingham, Alabama, on investigation of interfacial and graft polymerization procedures for producing weather-resistant cotton textiles with improved physical properties.

Research to develop new fluorochemical finishes for oil- and water-repellency and other reactive and additive finishes is conducted at New Orleans, Louisiana, to improve cotton's soil resistance. Additional research is being performed: (1) under contract at the Harris Research Laboratories, Inc., Washington, D. C., to provide fundamental information on the mechanism of the soiling of cotton by dry soils, and water-, oil- and solvent-borne soils, which could lead to the formulation of a general theory of the soiling of cotton and modified cotton; and (2) under a grant at the University of Arizona, Tucson, Arizona, on correlation of surface microtopography of treated and untreated cotton fibers with resistance to soiling of cotton textiles.

Research on flame resistant cotton textiles is performed at New Orleans, Louisiana. Recent emphasis has been on the development of treatments to impart flame resistance to cotton while at the same time imparting other desired textile properties.

Investigations of methods for imparting durable luster and related appearance characteristics to cotton textiles are carried out at New Orleans, Louisiana.

Research to improve cotton's bulk, elasticity and resilience through resin treatment, chemical modification, slack mercerization and other type swelling treatments, of fibers, yarns and fabrics is conducted at New Orleans, Louisiana. The research on fibers is aimed primarily at the development, by chemical or mechanical means or both, of more resilient and cohesive cotton batts for use in mattresses and other padding applications in the furniture and automobile industries. The cotton batting research is conducted cooperatively with the National Cotton Batting Institute, Textile Waste Association, National Cottonseed Products Association and the Foundation for Cotton Research and Education (affiliated with the National Cotton Council of America). Work on yarns is intended to produce bulky, elastic yarns suitable for weaving or knitting into fabrics with improved stretch and bulk characteristics. Investigation of a slack mercerization process, with and without subsequent resin treatment, is being carried out to achieve improved stretch cotton fabrics for industrial, household and apparel uses. Additional research on stretch and bulked cotton products is being carried out under contracts at North Carolina State College, Raleigh, N. C., on evaluation of stretch-type cotton yarns (prepared by backtwisting and false-twisting techniques) in knit wear; and on determination of optimum yarn constructions, knitting structures and prefabrication design for producing stretchable articles of knitted cotton wearing apparel by slack mercerization; and at Clemson Agricultural College, Clemson, S. C., on development

of cotton knit fabrics having increased bulk, warmth, and dimensional stability by application of finishing agents.

Research on the effect of yarn and fabric construction on the physical properties of chemically treated cotton fabrics is another phase of work at New Orleans, Louisiana. Research is in progress to determine the influence of yarn and fabric structures on the properties of stretch cotton fabrics produced by slack mercerization, with and without subsequent resin treatment.

The Federal in-house scientific effort devoted to research in this area totals 32.8 professional man-years. Of this total, 5.4 is devoted to weather resistant cotton fabrics, 1.0 to soil resistant cotton textiles, 6.6 to flame resistant cotton textiles, 2.5 to cotton textiles with improved luster, 14.6 to stretch and bulked cotton products, and 2.7 to effect of yarn and fabric construction on the physical properties of chemically treated cotton fabrics. The domestic contract and grant research involves an additional 6.9 man-years, 1.5 being on weather resistant cotton fabrics, 2.3 on soil resistant cotton textiles, and 3.1 on stretch and bulked cotton products.

The following lines of work were terminated during the year: (1) Design and development of acceptable cotton crepe apparel fabrics to compete with synthetic fibers in these markets, and (2) An engineering study of the feasibility and practicality of chemical and/or resin treatment of roving by continuous processing as an intermediate step in the mechanical processing of cotton (under effect of yarn and fabric construction on the physical properties of chemically treated cotton fabrics).

## PROGRAM OF STATE EXPERIMENT STATIONS

(A general program statement is given on page 84)

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Weather Resistant Cotton Fabrics

1. Improved Biocides, and Sunlight-Resistant Pigments for Cotton Textiles; and Improved Formulations, Equipment, and Procedures for Producing Outdoor Cotton Textiles. Cotton fabrics treated with the zirconyl ammonium carbonate - copper borate fungicides developed in cooperative research with the Canvas Products Association International and the Foundation for Cotton Research and Education have shown high resistance to rot in soil burial tests. The fabrics retained 100% of their strength after 5 weeks' burial. After 12 months of outdoor weathering, there is no evidence of growth of mildew and algae on the fabrics. Cotton duck treated with the copper zirconyl boroacetate finish has shown no evidence of microbiological attack and a high strength retention after fourteen months of outdoor exposure. Several companies interested in the treatment of outdoor cotton fabrics are already looking into the possibilities of these new finishes. Mineral dyeings of

cotton fabrics have been effected with certain chromium and nickel compounds solubilized and then redeposited with zirconium salts. These agents can be employed together with the copper borate - zirconium salt fungicides to impart light screening and antimicrobiological activity in a single treatment. The substantial areas of promising new research discovered will be investigated under new projects. (S2 1-156).

Experimental work has been initiated in contract research at Texas Woman's University to develop weather-resistant, water-repellent finishes for cotton. Following completion of a survey of commercial water-repellents, and the major part of a literature search covering the area of cotton water repellency, the contractor has applied a number of selected water-repellents to cotton duck and twill and placed the treated samples on exposure. These agents are from a list of approximately fifty water-repellents, including at least two from the twelve general types, compiled by the contractor. The application of finishes and their evaluation will continue. (S2 1-200(C)).

B. Soil Resistant Cotton Textiles

1. Fluorochemical and Other Soil Resistant Finishes for Cotton. Modification of cotton with fluorochemicals to impart durable water and oil repellency has proceeded along two lines--chemical reaction, and a combination of reaction and polymerization. Only the latter approach has yielded useful results to date. Ethylenimine has been found to be a useful material for linking the cellulose chain to long chain fluoroacyl compounds such as ethyl perfluorooctanoate. The latter treatment imparts durable oil repellency to fabric at low add-ons, and fair water repellency. Some progress has been made in developing methods of synthesizing alpha-chloroalkyl perfluoroalkyl ethers; however, due to instability of these ethers it has not been possible to obtain products of the desired purity for treatment of cotton. In other work, simple procedures have been devised for preparing primary and secondary perfluoroamines by sodium borohydride reduction of the corresponding perfluoronitriles and perfluoroamides, respectively. Although the amines themselves are not cellulose-reactive, they are capable of reaction with compounds such as THPC which are reactive with both cotton and the fluorocarbon. In certain cases this combination has given water and oil repellency although the treated fabric is colored and has poor tensile strength. Further work is in progress using this approach. Also, additional research will be conducted to improve the ethyl perfluorooctanoate-ethylenimine oil- and water-repellent finish. (S2 1-180, S2 1-250).

The in-house investigations of various finishes with respect to soiling and soil removal from cotton have been terminated. Further work showed that cotton fabrics with hydrophobic finishes or cationic surfaces require higher detergent concentrations in the wash to remove soil. Soil is readily removed from carboxymethylcellulose (CMC)-treated and phosphonomethylated (anionic) fabrics at low as well as high detergent concentrations. It was established that CMC can be added to crosslinking formulations based on triazines and ethyleneureas to produce wash-wear cotton fabrics with improved resistance

to aqueous and oily soils. The use of the CMC also makes soil easier to remove by laundering techniques. This improvement was durable through 25 launderings. A resin-CMC add-on of approximately 3-4% applied from a solution containing approximately 3-5% resin forming monomer and 2% medium viscosity CMC produced the best finish with respect to soil resistance and ease of soil removal. No problems were encountered in scaling up the application of these finishes to cotton fabric as evidenced by two successful pilot-plant runs. Industry has shown interest in this soil resistant finish. (S2 1-191).

Fundamental studies of soiling and soil removal in aqueous and oily systems, under a contract project at Harris Research Laboratories, Inc., have been completed. A comparison of the results of streaming potential and negatively charged soil (ferric oxide pigment) deposition measurements on cotton fabrics with various finishes showed that even relatively large changes in the degree of negative zeta potential of the fabric do not produce the expected corresponding change in deposition of the nagatively charged pigment. In another phase of work, the surface energy of cotton finishing materials as characterized by wetting measurements was determined to ascertain the relation between surface energy of the finishes and their tendency to become soiled and the ease with which soil is removed. It was found that the capillary structure of cotton fabrics substantially raises the critical surface tension for wetting above the value for smooth surfaces. The wettability by organic liquids of fabrics immersed in water is inversely related to their wettability in air. Silicone, fluorocarbon, and acrylic polymer finished fabrics immersed in water have strong affinities for organic liquids compared with untreated cotton. The deposition from water of hydrophobic solid soil onto cotton finishes increases with increasing oil wettability of the finish immersed in water. Hydrophilic pigment deposition does not depend upon the degree of oil wettability of the finish. Laundering at high temperatures causes the more polar oils to become firmly fixed to fabrics. In general, organic finishing agents more hydrophobic than cellulose make oily soil removal more difficult than from untreated cotton. (S2 1-175(C)).

Based on results from the completed research, new contract research has been initiated at Harris Research Laboratories to determine if a high energy interface between the surface of the fiber and its environment leads to heavy soiling in general. The effect of soiling environment on the soiling tendency of a series of selected cotton finishes will be determined and an attempt will be made to formulate a general theory of the soiling of cotton and modified cottons. The Southern Division has supplied base fabrics for initial phases of the soiling studies. A significant step has already been made by devising what appears to be a suitable dry soiling procedure for cotton. This is very important since no suitable method exists in which cotton can be dry soiled at a uniform level. (S2 1-223(C)).

C. Flame Resistant Cotton Textiles

1. Treatments to Impart Flame Resistance and Improved Textile Properties to Cotton. Research to develop improved treatments for imparting flame resistance and other desired textile properties to cotton has continued. Three new flameproofing formulations were prepared which impart good flame resistance to cotton at relatively low weight gains. Precondensates of THPC with tris(2-carbamoylethyl) phosphine (TCEP), tris(2-carbamoylethyl) phosphine oxide (TCPO), or phosphoroxytriamide (PTA) are employed and fixed on the cotton with ammonia. Cotton fabric treated with the THPC-PTA precondensate proved particularly interesting in that it showed essentially no strength loss after chlorine bleaching and scorching. Moderate flame- and rot-resistance and excellent crease resistance were simultaneously imparted to cotton fabrics by application of the methylol derivatives of TCEP and TCPO. The finishes are durable to repeated home launderings. In recent work it was discovered that good flame retardancy can be imparted to cotton textiles by fixing THPC alone in the textiles with ammonia. This process is simpler and cheaper than the earlier ones employing precondensates of THPC, and the finish is more resistant to removal by laundering. The process is undergoing evaluation in industry.

A continuous spraying technique has been successfully used to flameproof the surface of cotton pile rugs, napped blankets, and similar cotton products. This not only reduces significantly the chemical cost of flame retardants but also provides a more fluffy or bulky and resilient cotton product. (S2 1-190).

D. Cotton Textiles With Improved Luster

1. Processes for Imparting Durable Luster and Related Appearance Characteristics to Cotton Textiles. Cotton fabrics possessing the combined properties of permanent luster, excellent wash-wear characteristics, and extraordinarily high tearing strength have been developed in recent research. The process employed consists of weaving the fabrics from yarns mercerized under high tension and treating the fabrics with resins such as dimethylol ethyleneurea (DMEU). After as many as 35 launderings, the fabrics still retain considerable luster and extremely high wash-wear ratings. The luster obtained by weaving sateen from tension-mercerized yarn for the face of the fabric and unmercerized yarn for the back of the fabric was as great as the luster of sateen woven from tension-mercerized yarn for both warp and filling. This could reduce the cost of making a lustrous fabric.

The calendering without friction of DMEU-impregnated fabrics woven of premercerized yarn, and the subsequent resin curing of these fabrics, produced wash-wear fabrics with high luster and sheen without the undesirable gloss obtained when friction-calendering was used. Luster of uncalendered fabric and also the effects of friction calendering remained durable after 20 or more standard launderings, although there was some decrease in shine.

Several textile finishing companies are evaluating lustrous fabrics produced in the research. Fabrics with durable luster and the other properties achieved are in great demand for many types of clothing and household items. (S2 1-194).

E. Stretch and Bulked Cotton Products

1. New and Improved Processes for Production of Stretchable Cotton Yarns and Fabrics Using Chemical and Mechanical Treatments. Stretchable cotton yarns and fabrics that retain their elastic properties after repeated use are being developed through the application of thermosetting resins and various mechanical treatments. Twist studies have established that for a 24/2 stretch-type cotton yarn of optimum properties produced by the back-twist method (DMEU resin) a single yarn twist multiplier of from 4.0 to 4.5 "Z" twist, a ply twist multiplier of 7.0 "Z" twist, and a 15.0 twist multiplier in the "S" twist direction for backtwisting should be employed. Stretch-type yarns were produced having over 200% elongation-at-break and were woven into fabrics having over 100% elongation-at-break in the filling direction. Filling-stretch fabrics from yarns produced by the back-twist method using either DMEU or a triazine-type resin have shown good durability to home and commercial-type laundering procedures. The fabrics showed no appreciable losses in resin content or strength and only slight decreases in stretch after 60 commercial launderings. Research to determine the effect of fabric structure on the stretch and other physical properties of filling-stretch fabrics has indicated that change in either ends or picks per inch is equally effective in controlling the fillingwise stretch of the fabrics. This work will be extended to two-way stretch fabrics. Optimum structures of stretch fabrics will be designed for specific end uses. (S2 1-193 (Rev.)).

Conventional twist and high twist yarns spun from highly acetylated cotton roving produced good stretch yarns by the falsetwisting and backtwisting processing techniques. It is indicated that significant stretch will be obtained in woven or knitted fabrics prepared from such stretch yarns. Also, basic information obtained on the relationship of polymer content to the amount of stretch that can be imparted to cotton yarn by cyanoethylation and graft polymerization of acrylonitrile, followed by backtwisting, has shown that this is a promising approach for making textured and stretch yarns. Other chemical and mechanical means for producing the crimped elastic cotton yarns will be investigated. (S2 1-213).

Initial experimentation by the contractor (Clemson Agricultural College) in research to develop cotton knit fabrics having increased bulk, warmth, and dimensional stability by application of finishing agents has shown that a vacuum impregnation-centrifugation method of application imparts bulk to the fabrics. The best methods for applying, drying, and curing several finishing agents, including DMEU, APO, and an epoxide, are being established. Durability, dimensional stability, and warmth measurements will be made and related to the bulk imparted to fabrics thus far prepared. (S2 1-205(C)).

Experimental work was initiated in contract research at North Carolina State College on evaluation of stretch-type cotton yarns in knit wear. The contractor has established satisfactory knitting conditions and techniques to produce knit fabrics from 24/2 and 60/2 stretch-type cotton yarns made by the back-twist method. The 24/2 yarns will be used to produce socks and the 60/2 to produce T-shirts. The garments will be evaluated in in-service tests. Knitting experiments are in progress on stretch yarns made by the false-twist method so that satisfactory knitting techniques and optimum fabric structures may be established for this type yarn. (S2 1-197(C) (Rev.)).

2. New and Improved Processes for Production of Stretchable Cotton Textiles Using Slack Mercerization and Other Type Swelling Treatments. An improved method for producing stretch cotton yarns by slack mercerization has been found. It consists of crosslinking the cellulose while swelled in a mercerizing caustic solution. This process yields yarns having more shrinkage than usual, thus imparting a higher degree of stretch. The wet crosslinking also improves the recovery properties of the yarn. Development of practical processes to crosslink the cotton cellulose in its most shrunken condition should permit use of normal washing and drying operations on the yarns without reduction of stretch properties as occurs when wet slack mercerized yarns are restretched during washing and drying. (S2 1-213).

Coordinated research between the Southern Division and knitters, weavers, and finishers has contributed significantly to the rapidly advancing commercialization of stretch cottons. At least twenty companies in the U. S. are in commercial production of all-cotton stretch fabrics by slack mercerization. Most of the production is going into apparel, but upholstery and slip cover materials are also produced. Several other domestic companies plan to market the all-cotton stretch fabrics, and these fabrics are also being commercially produced in Canada, Japan, and Europe. Slack-mercerized all-cotton stretch socks are in limited production by one company, and indications are that additional firms are planning commercial production. Industry is also interested in molding and coating stretch fabrics.

3. Resilient and Cohesive Cotton Batts from Low Cost Cotton. Continued good progress has been made in the research on cotton batting conducted in cooperation with the National Cotton Batting Institute, the Textile Waste Association, the National Cottonseed Products Association, and The Foundation for Cotton Research and Education. Batting products giving improved recovery from deformation loading at both 60% and 100% relative humidity have been produced using certain spray formulations containing more than one resin or latex. Studies of drying and curing of resin/latex treated batting indicated that the pressure drop through the spray damp batt is critical during the drying phase and must be maintained below 0.5" of water, whereas pressure drop during curing is not nearly so critical. Only very slight improvement in product performance has been achieved thus far through use of mechanical processing techniques for random orientation of fibers in the batting array. However, the fiber orientation studies will continue both on equipment fabricated at SU and on commercial type equipment for nonwovens.

Emphasis in recent work has been on obtaining practical data on formulations, drying and curing variables, and product performance improvement to speed commercialization of the new cotton batting. Early commercialization seems assured. Based on satisfactory pilot-plant evaluations which they conducted, two companies plan to purchase drying and curing ovens for full commercial production of the products. These companies have installed pilot lines for the production of the new batting, and eight additional companies are in some stage of installing pilot lines. Tests on auto seat cushions by two major automobile manufacturers has resulted in tentative approval of the batting products for use in the 1965 models. (S2 1-181 (Rev.)).

F. Effect of Yarn and Fabric Construction on the Physical Properties of Chemically Treated Cotton Fabrics

1. Effect of Fabric Structure on Properties of Chemically Treated Fabrics. Research has been initiated to investigate the effect of yarn and fabric structures on the properties of cotton stretch fabrics produced by slack mercerization with and without subsequent resin treatment. The work has already led to products with improved stretch and recovery properties. The amount of easy filling stretch in plain and twill weave fabrics (slack mercerized, resin treated) was increased by using filling yarns the same size or smaller than the warp yarns, and by employing filling yarns with higher twist. In the latter case the percent growth after stretching also increased. The research results should enable companies producing slack mercerized fabrics to improve the performance of their products. Research will continue on one-way stretch fabrics and be extended to two-way stretch fabrics. To adequately satisfy all the potential markets for stretchable cotton fabrics, it will be essential that fabrics with two-way stretch be developed. (S2 1-226).

The research to determine the feasibility and practicality of chemical tretament of cotton roving was terminated. A versatile unit was developed for batchwise chemical treatment of roving in package form; it operates under controlled conditions over a wide range of processing variables with minimum package deformation during processing. With suitable modifications the apparatus could be adapted to continuous operations. The operating techniques devised for the new apparatus are applicable to dyeing as well as to resin and other chemical treatments. (S2 1-184).

The experimental work on production of acceptable cotton crepe fabrics has been completed by the contractor (Philadelphia College of Textiles and Science). Based on experimental weavings of small yardages of fabrics from the crepe-type yarns developed, a selection of the most satisfactory cotton crepe was made, and fifty yards of this fabric were produced for evaluation. Although it is possible to produce satisfactory cotton crepes, the cost involved is so high it is unlikely they will be able to compete with rayon crepes of the same weight. (S2 1-157(C)).

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COTTONSEED PROCESSING AND PRODUCTS
Southern Utilization Research and Development Division, ARS

Problem. Cottonseed products, currently approximately two billion pounds of oil and 2.5 million tons of meal derived from the annual domestic production of cottonseed, face increasing competition for markets. For its chief market, edible products, cottonseed oil must compete with other vegetable oils and animal fats. The nation's capacity for producing these oils and fats is so great that supplies can be expected to exceed both domestic and foreign demand for some time to come. Cottonseed meal, used chiefly as a protein supplement in feeding ruminant animals, faces serious competition from synthetic urea and other supplements. Improvements in the quality and utility of cottonseed oil are needed to retain present and open new markets for the currently large and possibly greater future production.

As an illustration, there is a discrimination in the markets against 25% to 50% of the current production of cottonseed oil due to the presence of reddish colors that are not removed by present commercial refining, bleaching and deodorizing methods. It is essential that information be developed on the chemistry of the pigments responsible for the off-colors, and that practical means be developed to eliminate them and thus upgrade the oils, particularly for use in margarine and shortening. Additional information is urgently needed on the chemical, physical, and biochemical properties of cyclopropene fatty acids in cottonseed and means of converting them, if found necessary, into physiologically inert forms. New types of modified fats, such as polyester and polymeric fats, need to be developed from cottonseed oil for applications in the fields of edible and inedible coatings, waxes, resins, plasticizers, and lubricants. Cocoa butter-like fats and other confectionery fats derived from cottonseed oil could also provide new markets for large quantities of oil. Fundamental information is needed on hydrogenation to permit production of improved plastic fats. Other areas in which markets for cottonseed oil need to be developed through research include fat emulsions for intravenous feeding, edible emulsifiers, and fatty acid amides and derivatives for use as plasticizers, plastic foams and other industrial products. Improvement in the quality and nutritive value of cottonseed meal is needed so that it can better compete with other protein feed supplements. Additional information is needed on the physiologically active constituents of the meal responsible for egg abnormalities, swine mortalities and growth abnormalities of young animals that limit cottonseed meal's usefulness in poultry and swine rations, and for the recently reported implication of cottonseed meal in the incidence of trout hepatoma which has resulted in its elimination from use in fish feeds in certain areas. Processing methods must be devised for the commercial production of meals that can be fed to broilers, laying hens and swine, safely and without restriction. In order to lay the necessary groundwork for advances in cottonseed research on food, feed and industrial products and processing technology, additional fundamental information is also needed

on the chemical composition and properties of cottonseed and of various cottonseed products.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving organic chemists, physical chemists, analytical chemists, biochemists, chemical engineers, physicists, and microbiologists engaged in both basic and applied studies on cottonseed and its products to develop new or extended uses for these materials.

Research to develop fundamental information on the chemical composition and properties of cottonseed products is conducted at New Orleans, Louisiana, as a basis for efficient applied research in the fields of food, feed, and industrial products from cottonseed. Some important phases of current work involve research on the chemical, physical and biochemical properties of cyclopropene fatty acids and other cottonseed constituents; and on fungi and toxic fungal metabolites which may develop in cottonseed and its processed products. The Foundation for Cotton Research and Education contributes towards research on the isolation and characterization of cyclopropene ring fatty acids of cottonseed. The National Cottonseed Products Association supports a Postdoctoral Research Associateship for conducting pioneering research on cottonseed and cottonseed constituents. Additional research on chemical composition and physical properties is carried out under contract at the University of Tennessee, Knoxville, Tennessee, on investigations of gossypol esters and mild oxidation products of gossypol and gossypol derivatives; at the University of Illinois, Urbana, Illinois, on investigation of the chemical and physical properties of cyclopropene fatty acids in cottonseed; and at Purdue Research Foundation, Lafayette, Indiana, on fundamental investigations of chemical transformations of olefinic compounds of fats and other agricultural materials by hydroboration and subsequent reactions to develop basic information for the production of useful products.

New and improved food products and processing technology are developed in research conducted at New Orleans, Louisiana. Methods are sought to produce improved cottonseed oils, and confectionery fats, polyester products, and fat emulsions for intravenous nutrition from cottonseed oil. The research on confectionery fats is cooperative with the National Confectioners' Association who maintain a Fellowship at the Southern Regional Research Laboratory, New Orleans, Louisiana, in partial support of the work, and evaluate promising research products. The Office of the Surgeon General supports the research on fat emulsions. This research is conducted cooperatively with the U. S. Army Medical Research and Nutrition Laboratory and several medical school research groups. Informal cooperation is maintained with industry in connection with the research on new and improved food products and processing technology. Additional research on new and improved food products and processing technology is conducted under contract at the University of Illinois, Urbana, Illinois, on chemical investigations of

cyclopropenoids to develop practical means of eliminating or physiologically inactivating the cyclopropenoid constituents of cottonseed oil.

Research is carried out at New Orleans, Louisiana, to develop new and improved feed products and processing technology for cottonseed. Investigations are in progress to isolate and identify the physiologically active constituents in cottonseed meals that adversely affect the utilization of the meal as a protein supplement in nonruminant feeding. Animal tests in connection with the overall research program are conducted through the cooperation of nutritionists in State Agricultural Experiment Stations and the Animal Husbandry Research Division. The Pharmacology Laboratory at the Western Regional Research Laboratory, Albany, California, cooperates by conducting small-animal studies to determine the physiological and pharmacological effects of cyclopropene acids and toxic fungal metabolites. In research directed toward providing a basis for the ultimate commercial production of cottonseed meals that can be fed to swine and poultry without restriction, as well as to ruminant animals, cooperation is maintained with the National Cottonseed Products Association, members of the cottonseed industry, and nutritionists in public and commercial agencies. Additional research in the field of new and improved feed products and processing technology is in progress under contract at IIT Research Institute, Chicago, Illinois, on development of practical processing methods for inactivation of cyclopropene groups in cottonseed meal that decrease its value as a feed for laying hens.

Research to develop new and improved industrial products and processing technology is conducted at New Orleans, Louisiana. Present emphasis is on amide derivatives of long-chain fatty acids. Informal cooperation is maintained with industrial firms for the evaluation of promising research products for specific end uses. Additional research on new and improved industrial products is being carried out under contract at the University of Arizona, Tucson, Arizona, on the polymerization of reactive chemical intermediates derived from cottonseed oil and other agricultural materials to produce polymers having potential industrial utility; and at U. S. Industrial Chemicals Co., New York, N. Y., on copolymerization of ethylene with unsaturated fatty acids and other selected derivatives of agricultural materials to extend their utilization in commercial plastics.

Other research on chemical composition and physical properties is in progress under grants of P.L. 480 funds to the following foreign institutions: British Food Manufacturing Industries Research Association, Leatherhead, Surrey, England, for fundamental studies of the fatty acid and glyceride composition of cottonseed oil and the crystallizing behavior of some of the major components (project duration - 4 yrs.); University of Bombay, Bombay, India, for a study of the relationship of substituent fatty acid groups on the physical properties of diacid triglycerides of palmitic and stearic acids as a means of increasing the utilization of cottonseed oil for food and industrial purposes (project duration - 5 yrs.); Israel Institute of Technology, Haifa, Israel, for investigation of $\pi$-complexed organometallic

compounds derived from polyunsaturated fatty acids to obtain fundamental information needed in expanding the utilization of cottonseed oil (project duration - 5 yrs.); University of Rome, Rome, Italy, for basic investigations on the physical and physicochemical properties of cottonseed proteins (project duration - 5 yrs.); and Commonwealth Scientific and Industrial Research Organization, Ryde, Australia, for an investigation of the chemistry and biological effects of cyclopropenoid compounds that occur in cottonseed and its products (project duration - 5 yrs.).

Additional research in the field of new and improved feed products and processing technology is in progress under a grant of P.L. 480 funds to Instituto Farmacologico "Mario Negri", Milan, Italy, for a study of the mechanism of gossypol toxicity counteraction by L-lysine (project duration - 5 yrs.).

Additional research to develop new and improved industrial products and processing technology is in progress under grants of P.L. 480 funds to the following foreign institutions: University of Montevideo, Montevideo, Uruguay, for research on the preparation, characterization, and evaluation of derivatives of gossypol for use as biologically active materials, ultraviolet absorbers, and other products (project duration - 5 yrs.); Indian Institute of Science, Bangalore, India, for studies of the addition of carbenes to unsaturated fatty materials derived from cottonseed oil to provide possible new outlets for utilization of the oil (project duration - 5 yrs.); and National Chemical Laboratory, Poona, India, for investigation of the synthesis and properties of new-type glycol mono alkyl ethers for control of water evaporation to extend the industrial utilization of cottonseed oil (project duration - 5 yrs.).

The Federal in-house scientific effort devoted to research in this area totals 50.9 professional man-years. Of this number 20.4 is devoted to chemical composition and physical properties, 17.2 to new and improved food products and processing technology, 9.6 to new and improved feed products and processing technology, and 3.7 to new and improved industrial products and processing technology. The contract research involves an additional 6.9 man-years, 2.4 being on chemical composition and physical properties, 0.9 on new and improved food products and processing technology, 1.9 on new and improved feed products and processing technology, and 1.7 on new and improved industrial products and processing technology. P.L. 480 research involves 9 grants, of which 5 are on chemical composition and physical properties, 1 on new and improved feed products and processing technology, and 3 on new and improved industrial products and processing technology.

The following lines of work were terminated during the year: (1) Engineering studies to develop a commercial process for preparing cocoa butter-like fat from cottonseed oils (under new and improved food products and processing technology); and (2) Pilot-plant development of a cottonseed extraction process using hexane-acetone-water solvent mixtures to a stage suitable for commercial evaluation (under new and improved feed products and processing

technology).

## PROGRAM OF STATE EXPERIMENT STATIONS

Station research on cottonseed utilization is directed toward increased feed use. When protein quality is poor, usually the lysine in the protein has combined chemically with sugars, with fatty materials or, in the case of cottonseed, with gossypol. Studies designed to determine the extent to which lysine has reacted and to better understand the reactions which interfere with proper protein utilization are in progress. High quality proteins in the rations of swine and poultry decrease costs. As a result of this emphasis, the chemical properties and biological significance of gossypol-protein complexes are of major concern. Experiments designed to elucidate the effects of proteolytic enzymes on gossypol-protein complexes have revealed that trypsin treatment results in liberation of more than half of the gossypol as gossypol-peptide compounds. To date no enzyme has been found that will split the Schiff base type of linkage between gossypol and the epsilon amino group of lysine in the protein. This study is continuing and attempts are being made to determine the sequence of the amino acids in the peptide-gossypol compounds.

Other studies include work on developing suitable methods and techniques for determining harvest-aid chemicals or metabolites that may remain as residues in cottonseed. The action of gossypol at various concentrations on the in vitro activity of selected enzymes and enzyme systems is being investigated. Investigations on the influence of gossypol in swine rations are continuing and have revealed that gossypol is eliminated at a rather slow rate from the liver and spleen of the pig. Other related research centers on determining the nutritional value of cottonseed meal in animal rations.

The total research on the utilization of cottonseed amounts to approximately 1.7 professional man-years.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Chemical Composition and Physical Properties

1. Chemical, Physical, and Biological Properties and Structural Factors of the Proteins. The composition, properties, structural factors and reactions of oilseed proteins and associated materials are being investigated in a program of pioneering research conducted by the Seed Protein Pioneering Research Laboratory. The fundamental information developed should lead to new concepts and possibly new applications for oilseed proteins, including cottonseed protein. Since peanuts were found to be an especially suitable experimental material and employed for much of the early pioneering research on seed proteins, the report of progress in the research is given in Area No. 7, "Peanuts Processing and Products," as in the previous report.

the cyclopropenoids will be sought.

In further work on analytical procedures for cyclopropenoid fatty acids, a method applicable to the determination of these acids in rancid cottonseed oils was developed. The stepwise hydrogen bromide titration procedure also can be used as a means of following the autoxidation of methyl oleate or glycerides, and will afford a useful new tool for investigation of the mechanism of autoxidation. By applying previously developed analytical methods to the analysis of crude oils from 25 species and varieties of cottonseed, it was found that these oils ranged from 0.56 to 1.17% in cyclopropene fatty acid content (calculated as malvalic acid). The development of analytical techniques for cyclopropene fatty acids, particularly micro or semimicro methods and a method applicable to meals, will be continued. (S4 1-105).

3. Chemical, Physical, and Physiological Properties of the Oil, Fatty Acids, and Derivatives. Feeding tests have been continued in an effort to ascertain whether the presence of physiologically active cyclopropene fatty acid constituents in cottonseed oil constitutes a real problem from the standpoint of utilization of the oil for food uses. Considerable data have been accumulated concerning the effects of ingestion of cottonseed oils containing various amounts of cyclopropenoids on the fatty acid composition of various tissues and organs of experimental animals but, generally, firm conclusions cannot yet be drawn. The tissues from rats fed different fractions of cottonseed oil at the Pharmacology Laboratory, WU, are currently being analyzed for fatty acid distribution. In addition, other tests have been designed to determine whether Halphen-negative oils incorporated into the diets of laying hens have physiological effects on egg quality. For one test, now completed, commercially refined oils were bleached with alumina treated with sulfurous acid to remove their response to the Halphen test; the eggs produced were normal with respect to distribution of fatty acids in yolk fats and the color and pH of yolks and whites. Other experiments are in progress to confirm these findings. Halphen-negative oils prepared by other chemical procedures are also being used in similar feeding tests on hens. (S4 1-105).

Further research has been conducted under contract at the University of Illinois on chemical and physical properties of cyclopropene fatty acids in cottonseed. Investigations of the Halphen reaction of methyl sterculate indicated that a red compound, $C_{20}H_{36}O_2S_2$, is one of the substances formed. One sulfur atom is eliminated upon reduction of this compound with zinc. Reduction of the mixed methyl esters from the seed oil of Sterculia foetida with lithium aluminum hydride yielded a mixture of hydrocarbons that was not resolved into its component parts. A 50% yield of sterculene was obtained when the reduction was carried out with pure methyl sterculate. Various chemical intermediates to model compounds for use in studies of the cyclopropene ring have been synthesized. Trans-2-phenylcyclopropyltrimethylammonium iodide was prepared for making the corresponding phenylcyclopropene compound. The expected cyclopropane was not obtained by reaction of

Substantial progress has been made in a basic investigation of the physical and physicochemical properties of pure isolated cottonseed proteins under a P.L. 480 grant at the University of Rome. A monodisperse major protein component has been isolated from the protein extracted from a glandless variety of cottonseed. Studies are underway on the chemical and physicochemical characterization of this protein fraction. Work under this project is expected to yield new and fundamental information concerning the nature of cottonseed proteins and the enzymes of the resting cottonseed in relation to amino acid metabolism. Such information is needed in the application of cottonseed proteins to human food needs. (UR-E15-(40)-33).

2. Chemical and Physical Properties of Pigments and Minor Constituents Including Cyclopropene Fatty Acids. In the contract research at the University of Tennessee on gossypol esters and mild oxidation products of gossypol and its derivatives, two crystalline products have been isolated from the early stages of alkaline hydrogen peroxide oxidation of gossypol. One of these contained ethyl alcohol of crystallization. Tentative structures for these products have been proposed. Other work has resulted in the discovery and identification of a highly colored, purple-brown hydroxyquinone pigment formed by oxidation of gossypol under very mild conditions (by the action of limited amounts of oxygen on aqueous alkaline solutions of gossypol). The quinone is purple in alkaline solutions and red in acidic solutions. It is not alkali-fast, and the red color it imparts to cottonseed oil fades on exposure of the oil solution to light. The chemical properties of the quinone will be investigated. The information being developed will be of value in research on the problem pigments of off-colored cottonseed oils and on the problem of the metabolic fate and physiological properties of gossypol in animals ingesting cottonseed products. (S4 1-103(C)).

Extensive fundamental investigations of the cyclopropene fatty acid constituents of cottonseed oil have continued along several lines in in-house research. Several new procedures for removing or inactivating these constituents have been developed. Heat treatment of the oil with certain acids, including cottonseed acids, capric acid, citric acid, oxalic acid and formic acid, was employed in processes for production of Halphen-negative oils. Halphen-negative oils prepared by these chemical procedures will be fed to laying hens to determine physiological effects on egg quality.

Only limited success has been achieved in further purification of methyl sterculate by crystallization procedures. Maximum purity of product was about 83 percent. However, N-benzylsterculamide -- a crystalline cyclopropenoid which is solid at room temperature -- was prepared in 87% purity. Repeated solvent crystallization of methyl esters of cottonseed oil and Hibiscus syriacus has yielded products containing 15% and 25% methyl malvalate, respectively. Low-temperature crystallization techniques were scaled up in pilot plant experiments to produce sizeable quantities of cottonseed methyl esters rich in malvalate (about 10% concentration) for possible use in animal feeding tests and other phases of the cyclopropene research program. Procedures for obtaining still higher concentrations of

benzylethylene oxide and triphenylcarbethoxymethylene phosphorane. Effort is also being made to develop better methods for isolation of cyclopropene fatty acids. Countercurrent distribution of methyl esters from an oil sample low in methyl sterculate gave some enrichment in methyl sterculate, but separation was incomplete. Urea clathration remains the superior method for isolation of sterculic acid and its methyl ester. The fundamental information being developed should provide a basis for improving analytical methods for cyclopropene acids and facilitate development of improved procedures for removing or inactivating the cyclopropenoids of cottonseed oil.(S4 1-104(C)).

In resumed work on investigations of solubilities of long-chain fatty acids and their derivatives, additional solubility data for the pure cyclohexylamine salts of capric, heptadecanoic, and elaidic acids in methanol were obtained to complete these solubility curves. A number of additional methods of correlation and prediction of solubilities of fatty acids and derivatives (not necessarily homologs) have been worked out theoretically from thermodynamic principles and tested sufficiently to show their feasibility. It is proposed to complete the development of and make use of these and additional methods under a new research project. (S4 1-88).

Fundamental information on the chemical transformation of olefinic compounds of fats by hydroboration and subsequent reactions has been developed in contract research initiated at Purdue Research Foundation. Organoboranes were synthesized from olefinic ethers, and the resulting alkoxyorganoboranes were coupled to produce the respective dimers. 1,8-Dimethoxyoctane, 1,22-dimethoxydocosane, 1,8-diphenoxyoctane and 1,22-diphenoxydocosane were prepared from 4-methoxybutene, 11-methoxyundecene, 4-phenoxybutene and 11-phenoxyundecene, respectively. Preliminary experiments were conducted with olefinic esters, and 1,22-docosanedioic acid was prepared from methyl 10-undecenoate. The systematic study of hydroboration of olefins containing various functional groups will continue. The research results should provide a basis for preparation of potentially useful products from fatty acid olefinic compounds. (S4 1-112(C)).

In P.L. 480 research at the British Food Manufacturing Industries Research Association, studies are in progress on the fatty acid and glyceride composition of cottonseed oil and the crystallizing behavior of some of the major components. The fatty acid composition of a number of oils from cottonseed of various origins and processing histories have been examined by several different methods. Gas-liquid chromatography yielded results nearest to the accepted true values. Fractionation by low temperature crystallization has indicated that, although cottonseed oil contains 3 major component fatty acids, only 4 out of 26 probable triglycerides occur to the extent of over 8%, and the minor component acids are very uniformly distributed throughout the glyceride components of the oil. Additional information is being sought through the application of techniques such as countercurrent distribution, thin layer chromatography and lypolysis employing lipases. Further progress in the research is expected to provide data useful in the selection and processing of cottonseed oils for the commercial production of improved salad oils in optimum yields. (UR-E29-(40)-26).

In P.L. 480 research at the University of Bombay, studies are being made of the relationship of the substituent fatty acid groups to the physical properties of diacid triglycerides of certain saturated fatty acids, including those that occur normally in cottonseed oil. The diacid triglycerides that are of interest in this work are those containing one or two molecules of palmitic or stearic acid, and two or one of even-carbon saturated fatty acids of the series from acetic to stearic acid. Pure 1,3-diglycerides have been prepared and work is underway to prepare pure 1,2-diglycerides, from which the corresponding diacid triglycerides are synthesized. Progress is being made in determining the properties of the synthesized diacid triglycerides and their binary mixtures. The information obtained is expected to provide the basis for the further development of fats and oils specifically tailored for special food and industrial end uses. (UR-A7-(40)-3).

Research is just getting underway under a P.L. 480 grant at the Israel Institute of Technology (Technion) in which a basic investigation is being made of π complexed organometallic compounds derived from polyunsaturated fatty acids that occur in cottonseed and other fats and oils. Progress in the initial stages of the work has been made in applying the reactions to certain model compounds to develop techniques for extending the reactions to the polyunsaturated fatty acids. It is expected that the information obtained in later stages of the research will indicate opportunities for increasing the use of fatty acids from cottonseed and other oils through the development of new or expanded industrial applications. (UR-A10-(40)-34).

4. Investigation of Occurrence, Determination, and Properties of Fungi and Toxic Fungal Metabolites Which May Develop in Cottonseed and Its Processed Products. Research was recently initiated to isolate, identify, evaluate, and control the fungi and toxic fungal metabolites which may develop in cottonseed and its processed products. The importance of the potential problem of various agricultural commodities becoming contaminated with toxic microbial products is receiving increasing recognition.

Major emphasis in initial work has been on development of basic analytical methodology. The unique pigmentation problems in cottonseed meals and meats necessitated the development of a new analytical method for determination of aflatoxin in these products. Extraction solvents and procedures for removing interfering gossypol pigments from the extracts were studied to devise suitable procedures. The lower limits of detection of aflatoxin are presently being explored. In other experiments, a sample of deteriorated cottonseed (acid delintered) was found to be contaminated internally with Penicillium notatum, a mold in the P. oxalicum series, and a Cladosporium sp. Organisms found in the whole, crushed seed were A. elegans, 2 species of Penicillium, A. niger, A. awamori, A. niger gr., Rhizopus nigricans, and A. amstellodami.

Several selected commercial cottonseed meals were exhaustively extracted successively with ethyl ether-ethanol and ethyl ether-ethyl acetate to obtain extracts for use in cooperative studies on trout hepatoma with the

Western Fish Nutrition Laboratory, U. S. Department of Interior, and others. Attempts are being made to determine if the extracted components -- whether inherent in or adventitious to the meals -- contribute to the incidence of liver cancer in hatchery fish. The possibility exists that mold contamination of trout diets could be responsible for the hepatomas. (S4 1-116).

B. New and Improved Food Products and Processing Technology

1. New Edible Oil Products Including Confectionery Fats, Food Coatings and Other Specialty Products. A process has been developed for preparation of an improved cocoa butter-like fat by the direct esterification of the diglycerides of palmitic and stearic acids with oleic acid. It was found that most of the approximately 20% of unwanted, high-melting fats formed during the esterification can be removed by a relatively simple fractionation (crystallization) process. The cocoa butter-like fat product has the properties desired in a confectionery fat, including a short melting range, brittleness at room temperature, and good compatibility with cocoa butter. Larger quantities of the product will be prepared for evaluation. A commercial propylene glycol monostearate was also successfully esterified with oleic acid. Although the esterified product has too low a melting range (5°-15° C.) to be used as a cocoa butter-like fat, it may have other confectionery fat uses. Further work will be conducted on the direct esterification process.

Additional research on the previously developed method for rapid tempering of fats showed that increasing the orifice diameter of the homogenizer from 1/16 inch to 1/8 inch did not change the amount of mechanical working necessary to temper super-cooled, liquid cocoa butter. Both milk chocolate and chocolate liquor were successfully tempered by mechanical working, temperatures between 25° and 30° C. proving best. Satisfactory results were obtained by a commercial concern in test pilot-plant runs to evaluate the rapid tempering process for confectionery coatings. The research on confectionery fats is supported in part through a Fellowship sponsored by the National Confectioners' Association. (S4 1-125, Pending).

In recent research to develop new polyester products from cottonseed oil, emphasis has been placed on processes involving direct esterification of amylose with fatty acids. Further examination of products prepared by simple catalytic esterification of amylose with palmitic acid using dimethylsulfoxide as solvent revealed that the solvent entered the reaction and sulfur-containing esters were present in the products. This would make these particular products unsuitable for edible uses. A partially acylated amylose was prepared by dissolving the amylose in dichloroacetic acid and esterifying with fatty acid in hexane solution under conditions which remove water of esterification as it is formed. Research will be continued to establish optimum conditions for esterifying amylose in dichloroacetic acid solution. Amylose esters of long-chain fatty acids have attracted some industrial interest; and development of suitable methods for their preparation should facilitate their introduction and utilization, especially in

food coatings. A commercial firm is currently evaluating samples of the acetate, palmitate, and stearate esters of amylose as edible coating systems for freeze dried foods.

In further investigations of fungistatic activity of fatty acids and fats, experiments using the paper disc test method showed that growth of all types of molds studied was inhibited by caproic acid and tripropionin; growth of four Phycomycetes was retarded by trinonanoin, tridecanoin, triundecanoin, and triundecenoin; and growth of Rhizopus nigricans was temporarily prevented by triundecanoin and triundecenoin. (S4 1-90).

Improved fat emulsions for intravenous nutrition have been developed in research supported by the Office of the Surgeon General and conducted cooperatively with the U. S. Army Medical Research and Nutrition Laboratory and several medical school research groups. Animal tests of the individual emulsifiers of the previously developed SR emulsion 695 indicated all to be physiologically nonreactive if purified correctly. Modified emulsion 695 (reduction in emulsifier concentration) also was physiologically satisfactory. SR 695 or its modified form is ready for commercial preparation, and further development work on these particular emulsions is not contemplated at this time. New type, physically stable emulsions of cottonseed oil and of soybean oil have been formulated employing pure egg lecithin as the sole emulsifier. This was made possible by the successful development of a more efficient and higher yielding chromatographic method for isolation of the lecithin. The physical stability of the new emulsions is satisfactory at a 1 wt. % concentration; a pH of 6.6-6.8 is optimum. An isotonic solution of glycerol is employed as the aqueous phase in these emulsions. The lecithin-stabilized emulsions had no adverse effect on blood pressure of test animals. Extensive physiological evaluation of a soybean oil emulsion (SR 151) in animals is now in progress at three cooperating institutions; a cottonseed oil emulsion (SR 152) will be evaluated in the near future. (SU-0-0-2(SG)).

2. Processing Technology Related to Improved Oil Products, Including Modifying or Eliminating Cyclopropene Acids in Cottonseed Oil. Completed engineering studies have laid the basis for and indicated the feasibility of developing a laboratory interesterification process for preparing cocoa butter-like fats into a commercial scale process. The effect of additional modifiers on shortening crystallization times in the various processing steps of the conventional two-solvent (acetone-hexane) process were investigated in recent bench-scale experiments. Palmitic acid gave the best yields for separating crude cocoa butter-like fats from fat-acetone miscella, but the yields were not as high as those previously obtained when the saturated fats separated from the first crystallization were used as a modifier. None of the modifiers investigated for accelerating the separation of the crude cocoa butter-like fats gave yields comparable to those obtained using the conventional long holding times. In tests of the second crystallization phase of the process employing a scraped-surface crystallizer, it was established that filtration rates of the acetone-fat slurries quick-cooled in the

crystallizer can be increased by increasing retention time after cooling beyond four minutes. In the purification step, employing hexane, a minimum cooling time of 90 seconds was found necessary to obtain a slurry whose filtration rate does not adversely change with increased holding time. A one-solvent (hexane) process for producing cocoa butter-like fats was also investigated but proved unsatisfactory. (S4 1-101).

A practical batch process for bleaching off-colored cottonseed oils with activated alumina has been developed through the pilot-plant stage. Test runs in the 200-pound batch pilot plant gave results closely comparable to those obtained in the smaller bench-scale tests. A commercially available alumina, quoted at 10.5 cents per pound, was employed at a dosage of 4% in the pilot plant experiments. A major producer and processor of cottonseed oil has conducted engineering cost analysis of the process and has scheduled plant-scale tests for the near future. Recent research demonstrated the regenerability of the commercially available alumina proposed for the "in plant" testing, thereby removing the last technical obstacle to commercial employment of the bleaching process.

Work is in progress to develop methods for upgrading the quality of cottonseed oils by improving the color and eliminating undesirable components such as cyclopropene acids. Alumina bleaching followed by steam deodorization reduced the malvalic acid content of a color-reverted oil from 0.59% to 0.08%, and reduced oil color from 8.5 red to 2.9 red. Treatment of the same oil with alumina gel, precipitated on bleaching earth with sulfurous acid, gave a Halphen-negative oil but had no significant bleaching effect. Use of activated alumina and alumina gels in combination with other chemicals will be investigated. (S4 1-92, S4 1-114).

The contractor (University of Illinois) has made good progress on chemical investigations of cyclopropenoids as a basis for developing practical means of eliminating or inactivating these type constituents present in cottonseed oil. The cyclopropenoid -- 1,2-diethylcyclopropene -- was synthesized by the photolysis of diazomethane in the presence of 3-hexyne. It has been isolated in pure form and characterized. Three of the major pigmented components of the reaction of this compound with a solution of sulfur in carbon disulfide (Halphen-test reaction) have been isolated in chromatographically pure form; one of the components has been identified as cis-1,5-diethyl-2,4-dithiabicyclo-(3.1.0)-hexane-3-thione. This is the first Halphen-test reaction product that has been isolated and identified. It lends support to the view that the mode of action of cyclopropenes in living organisms may be by way of reaction of cyclopropenes with SH sites of enzyme systems. This could afford a satisfactory explanation of the observed unusual physiological activity of cyclopropenoids. Partly as a result of this, research on the effect of cyclopropenes on specific purified SH-containing enzymes has already been initiated in the Seed Protein Pioneering Research Laboratory. (S4 1-107(C)).

C. New and Improved Feed Products and Processing Technology

1. Basic Research to Improve Nutritive Value of Cottonseed Meal for Poultry and Swine, Including Investigations of Physiologically Active Constituents. As a basis for further improvement of the protein quality of cottonseed meals, research investigations are in progress to obtain a thorough understanding of the composition of cottonseed proteins and their location anatomically. The hypocotyl and cotyledon of the cottonseed have been found to differ in their amino acid patterns; the hypocotyl is higher in lysine, threonine, isoleucine and leucine, and it is lower in arginine, aspartic and glutamic acid. The evidence that amino acids important to nutrition of animals are more concentrated in the hypocotyl may open the way for further improving protein quality of cottonseed products. Aqueous extracts (deionized water) of the hypocotyl and cotyledon show similar electrophoretic patterns, but only one band in these patterns shows characteristics similar to the five major bands noted on electrophoresis of the protein bodies of the cottonseed. The proteins of the protein bodies are generally characterized by low lysine and high arginine and glutamic acid contents. Analyses to determine the amino and fatty acid patterns of members of the genus Gossypium were carried out and much of the work has been completed. Preliminary data indicate that the amino acid pattern noted for seed from upland cotton may be characteristic of the genus.

Investigations to identify the factors in cottonseed meal that cause mortalities among swine have continued. Feeding tests with swine to locate lethal cottonseed meals have been completed. With three meals, mortalities varied from 87% to 100%. Commercial hexane-extracted meals (containing about 1% residual oil) caused 100% mortalities. No toxicities were noted in the case of the mixed solvent meals (meals extracted with acetone-hexane-water mixture) and, moreover, shoats fed these meals outgained those fed a soybean meal selected for comparison by the National Soybean Council of America. Comparison of a meal causing 100% mortalities in swine with a mixed solvent meal has been made in recently completed rat feeding tests at the Pharmacology Laboratory, WU. Tissues from the animals are being analyzed at the Southern Division. Feeding tests with laying hens seem to indicate that abnormalities in the fatty acid distribution in egg fat are associated with constituents in cottonseed oil. Various cottonseed pigment gland fractions, separated on the basis of solubility, were fed to laying hens in cooperative experiments with Ralston Purina Co. to determine physiological effects of different forms of bound gossypol. These fractions, as well as gossypol, caused decreases in egg production, egg size, feed intake and weight of hens, as well as egg normalities in yolk pH, pink whites and yolk discoloration. Examination of meals and of tissues from animals fed cottonseed products will be continued. (S4 1-110).

2. Processing Technology Directed Toward Improving Meals. The pilot-plant development of the mixed solvent (acetone-hexane-water) extraction process for cottonseed is essentially complete and the process is now considered ready for evaluation in commercial plants. The process can be easily adapted to existing basket extraction plants without additional extraction facilities if 1% residual lipids in the meal is satisfactory. Auxiliary

immersion extraction equipment would be needed to reduce residual lipids to about 0.5%. A horizontal immersion extractor with an inclined draining section, to replace the previously used inclined extractor, has been designed, installed and test operated satisfactorily. In pilot-plant tests, commercial-type equipment and processing conditions for desolventizing oil and meal gave satisfactory results in the mixed solvent process. Preliminary evaluation of capacitance instruments indicated that they can be successfully used in controlling the mixed solvent composition to the values selected, and in automatically controlling the solvent recovery and remake operations. The crude miscella from the mixed solvent extraction process has been miscella refined in a batch process to produce a prime bleachable oil, with nearly complete recovery of neutral oil. A typical plant layout and flow sheet for the new extraction process has been prepared, and cost estimates have been developed for new plants and for converting existing plants to mixed solvent extraction for capacities of 200 and 400 tons of cottonseed per day.

Two 1-ton lots of cottonseed meal having residual lipids contents of 0.7% and 1.0%, low free and total gossypol contents, and high available lysine contents were produced in the pilot plant by the mixed solvent process for use in feeding tests with swine, broilers, and laying hens. In swine feeding tests, these meals have equaled or exceeded soybean meal and greatly exceeded commercial cottonseed meals in performance. Excellent results were also obtained in feeding broilers, and additional tests are underway on broilers and laying hens.

New research will be initiated to investigate the processing characteristics of glandless cottonseed, and the refining and bleaching of cottonseed miscellas and oils of high gossypol content. (S4 1-111).

A study of rates of extraction of the oil of cottonseed with acetone-hexane-water solvent mixtures, and the properties of the marcs and miscellas, has been initiated to provide information basic to the production of processed cottonseed products of the highest quality. It was demonstrated that a very rapid and substantially complete extraction of oil from raw, moist cottonseed flakes can be achieved with acetone-hexane-water azeotrope in a four-step countercurrent extraction if light pressing (ca 100 psi for about 40 seconds) is employed between each pass in the extraction. Extraction time was about 3 minutes, and residual oil in the air dried marc was approximately 0.1%. The solvent-damp marc tends to form a plastic mass when it is kneaded in desolventization operations. The compositions of miscellas and properties of the marcs obtained by the azeotropic extraction will be investigated. (S4 1-123).

D. New and Improved Industrial Products and Processing Technology

1. Basic Research to Develop New Reactions and Products Suitable for Industrial Use. Additional N-disubstituted fatty amides have been prepared, characterized, and evaluated as polyvinyl chloride plasticizers. They will

be submitted for screening evaluations for antimycotic activity. The N-dialkylamides, a new class investigated, proved particularly interesting since preliminary results indicated their thermal stability was much better than that of most of the amides so far investigated, and they gave exceptionally low brittle points. Recent work on this class of amides -- specifically N,N-dialkyloleamides -- has indicated that as the size of the alkyl group increases, the volatility loss decreases. Brittle points were lowest for the n-butyl derivative (-63° C.) and the n-amyl derivative (-61° C.); beyond the hexyl derivative, the dialkyloleamides are incompatible. The n-butyl derivative has a markedly lower volatility loss, and gives a lower brittle point than the isobutyl derivative. It is comparable to dioctyl sebacate, a commercial plasticizer, which gives a brittle point of -65° C. The effect of acid moiety on properties of the N-dialkylamides will be investigated.

Plasticizer performance of the N,N-bis(2-methoxyethyl)- and/or N,N-bis(2-ethoxyethyl)amides of a number of fatty acids (including palmitic, stearic, oleic, linoleic, erucic, epoxystearic, dimer acids, parsley seed acids, rapeseed acids, L. douglasii acids, and selectively hydrogenated cottonseed acids) was also determined. All except the linoleic acid derivative exhibited good compatibility in vinyl chloride plastics. The N,N-bis(2-ethoxyethyl)stearamide is apparently the first compatible plasticizer containing the stearic acid moiety that has been found. In general, these amides are more efficient than dioctyl phthalate (DOP) and most of them, including the amides of the seed oil acids, give lower brittle points (-45° to -57° C.) than DOP (-33° C.). Many are thus comparable to dioctyl adipate (-55° C.) without the objectionably high volatility loss of the latter. The N,N-bis(2-ethoxyethyl)amides of epoxystearic and dimer acids gave lower brittle points than other amide derivatives of these acids so far studied, and the epoxy derivative exhibits a thermal stability equal to that of DOP and can be used as a compatible stabilizer. The N-dialkoxyalkylamides, as a class, appear to have good potential as specialty low-temperature plasticizers for polyvinyl chloride. Selected ones will be evaluated as softeners for nitrile rubber.

Based on earlier Southern Division research on piperidides of long-chain fatty acids, a chemical company is planning pilot-plant scale preparation of one of these plasticizers for test marketing. (S4 1-99, S4 1-124).

Further progress has been made in P.L. 480 research at the University of Montevideo, Uruguay, in the preparation, characterization and screening of a number of derivatives of gossypol having potential industrial utility. Several new imino derivatives (anils) have been prepared. Reduction of these to substituted amines by catalytic hydrogenation at moderate pressures has not been successful. However, use of higher pressures, or reduction by means of agents such as lithium aluminum hydride or sodium borohydride, is expected to yield derivatives having ultraviolet screening or antioxidant properties. Derivatives that have been prepared by reaction with hydantoin would be expected to exhibit physiological activity or catalytic activity

in certain organic reactions. Two classes of gossypol derivatives with carboxyl groups in the molecule have also been prepared. These compounds may have fungicidal or germicidal properties. Screening for such potential uses is being considered. (UR-S9-(40)-2).

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## CLOTHING AND TEXTILES FOR CONSUMER USE

Clothing and Housing Research Division, ARS

Problem. To choose wisely from the wide variety of textiles available on today's market, consumers need information on the properties imparted to textiles by cotton and other fibers and on the properties textiles need for satisfactory performance in specific uses. Also needed by consumers are improved sizing systems for patterns and ready-made clothing, including shoes, and designs for garment features that will contribute to the comfort, safety, and efficiency of the wearer. To provide guidance to homemakers in keeping the family's supply of clothing and household textiles in good condition, research-based information is needed on soiling and soil removal, on causes and prevention of fabric deterioration, and on survival of pathogenic and odor-producing microorganisms on fabrics.

### USDA AND COOPERATIVE PROGRAMS

Investigations include studies of the relationship of in-use performance of fabrics of cotton and cotton blends with laboratory determinations of such properties as elastic behavior and resistance to abrasion. Principles of construction for use in making, repairing, or altering clothing and household textiles are developed. Anthropometric data are obtained as a basis for the sizing of apparel, including shoes. Also investigated are the nature of soil and its removal from fabrics; the nature, causes, and prevention of undesirable changes in fabrics; and the role of fabrics in the dissemination of microorganisms and means of control.

The Federal scientific effort devoted to research related to cotton products totals approximately 6.0 professional man-years. The Department's research facilities are located in Beltsville, Maryland.

### PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in both basic and applied research on textile fibers and properties and on the end-use performance of fabrics, clothing and household items.

In the Southern region textile specialists are studying cotton fiber properties and have made tests to evaluate the effect of elongation on the lasting qualities of household textiles. Sheets were selected as the test items. Additional cotton fiber properties, such as length, strength, and fineness, will be studied. This is basic research of importance to both the consumer interested in long-wearing household items and to the cotton producers who face the problem of marketing a fiber of known potential.

Researchers in the Western region are studying the effect of environmental conditions on cotton fabric. Atmospheric factors considered were air pollution, light, wind velocity, temperature, airborne dust, and moisture. The research is designed to yield insights regarding the degradation of cotton fabrics under use conditions and to explain the type of damage resulting from specific atmospheric exposures. As understanding develops, special fabric treatments to counteract effects can be considered.

In the North Central region research was recently completed on criteria for selection and use of girls' clothing. Winter skirts were used as test items. Basic work is being initiated dealing with fabric behavior under minimum stress conditions, such as pull, bending, and abrasion. Different fiber content, fabric geometry, and types of finishes will be studied. Broad principles are being sought which will apply, within reason, under changing market conditions.

Textile specialists and social scientists have joined forces in the Northeastern region to study the attributes of consumer satisfaction in relation to laboratory and other wear tests. This research is ongoing and again general principles useful to both the consumer and the manufacturer are sought.

Other projects deal with the comfort of clothing of varying fiber content, with the relationship of price to quality characteristics of various items and with the analysis of residual soil remaining on fabrics after laundering and the means whereby soil remains attached to fabric.

## PROGRESS-USDA AND COOPERATIVE PROGRAM

### A. Performance of Fabrics for Clothing and Household Textiles

Plain and double knit cotton fabrics suitable for outerwear were manufactured to specification from three sizes of yarn with varying numbers of courses per inch under contract with the Philadelphia School of Textiles and Science. Elongation and elastic recovery are being determined when the fabrics are new and after one and five launderings.

### B. Transmission of Microorganisms by Textiles and its Prevention

Using Staphylococcus aureus as a test organism, the influence of fiber type (including cotton), fabric construction, water temperature, and type of natural soil on redeposition of bacteria on fabrics is being studied under controlled conditions which simulate home-type laundering.

Research was initiated to determine whether microorganisms of importance in household hygiene survive drycleaning and if so, whether they are transferred from one fabric to another during the cleaning process. Cotton fabrics typical of those commonly drycleaned are included in this research.

Studies with pine oil disinfectants in home-type laundering showed that when used in adequate amounts, products containing 80 percent pine oil were comparable in effectiveness to phenolic disinfectants. The findings were included in a paper on disinfectants for home laundering presented at the 1964 annual meeting of the American Society for Microbiology.

Research was initiated under contract with the Southern Research Institute for quantitative studies of the survival and infectivity of viruses after inoculation of fabrics by contact, droplet nuclei (aerosols) and dust. Cotton fabrics being used are sheeting and jersey.

C. Removal of Soil and Prevention of Undesirable Changes in Textiles

Research is continuing on interactions between cotton fabrics and sodium hypochlorite bleach as a factor in the deterioration of cotton fabrics in home-type laundering. Studies on deterioration of the unsoiled fabrics are complete, and similar studies are in progress on fabric which has been soiled with oily compounds typical of those found in natural oily soil.

Other research indicates that reaction of low concentrations of oxides of nitrogen (such as may be found in gas dryers and as contaminants in the atmosphere) with nitrogenous soil contributes to the yellowing of cotton garments. A technical article based on the results of this research has been accepted for publication in the American Dyestuff Reporter.

Studies are nearing completion of the whitening effects on fabrics of different fiber content of five chemically different types of fluorescent whitening agents under conditions simulating those used in home-type laundering. Fabrics used include one all-cotton, two cotton blends, and three resin-finished cottons. Six of the ten whiteners studies (all of which were described by the manufacturers as typical of those used in detergent formulations) were completely or almost completely ineffective when hypochlorite bleach was added to the whitener-containing wash water before introduction of fabric. These six whiteners were three stilbene and three coumarin compounds. One benzidence sulfone, one benzoxazole, and two benzimidazole whiteners retained their effectiveness. All ten whiteners retained their effectiveness in the presence of perborate bleach. All decreased in effectiveness when the fabrics were dried outdoors in sunlight. A paper based on this research was presented by invitation at the February 1964 meeting of the Washington Section of the American Association of Textile Chemists and Colorists.

D. Information for Consumer Guidance

Development of procedures for estimating yardage, cutting, making, and hanging draw curtains was completed. A report developed primarily for use by extension workers and teachers is now being reviewed within the Division. Manuscripts for two popular-type publications, one on clothing repair and the other on pattern alteration, are ready for review by the Information Division.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Removal of Soil and Undesirable Changes in Textiles

Furry, M. S. 1963. Detergents for Home Laundering. Home and Garden Bul. No. 49, 8 pp., illus. (Sl. Rev.)

McLendon, V. I. 1964. Removing Stains from Fabrics: home methods. Home and Garden Bul. No. 62, 30 pp., illus. (Sl. Rev.)

Transmission of Microorganisms by Textiles and Its Prevention

Furry, M. S. 1964. How to Prevent and Remove Mildew: home methods. Home and Garden Bul. No. 68, 14 pp., illus. (Rev.)

McNeil, E. (Chairman), Blandford, J. M., Choper, E. A., Graham, R. T., Hoak, F. C., Oliva, E. C., and Smith, J. C. 1963. The Role of Bacteria in the Development of Perspiration Odor on Fabrics. Am. Dyestuff Reptr. 52(25), pp. 87-90. (1963 Annual Intersectional Technical Paper Competition, AATCC.)

McNeil, E. 1964. Dissemination of Microorganisms by Fabrics and Leather. Develop. in Indus. Microbiol., V. 5, pp. 30-35.

McNeil, E. 1964. Sanitation in Home Laundering. Home and Garden Bul. No. 97, 8 pp., illus.

# III. MARKETING AND ECONOMIC RESEARCH

## COTTON AND COTTONSEED - MARKET QUALITY
Market Quality Research Division, ARS

**Problem.**

Cotton: Technological advancement in production, harvesting, and ginning of cotton brought on by mechanization has resulted in changes in the quality of cotton fiber which are not recognized by present methods of quality evaluation. Mill operators, both domestic and foreign, have reported that these changes have reduced the spinning quality of cotton, thus increasing processing costs and lowering the value of finished products. Precise information is needed on the processing performance and manufactured product quality of cottons which have been subjected to various production, harvesting, and ginning practices in preparation for markets. New and improved techniques, devices, and procedures for measuring quality factors of cotton fiber are needed to provide better grading and standardization of lint cotton, and indicate the true processing performance and manufactured product quality.

Cottonseed: Cottonseed is subject to deterioration in quality and loss in value through fungus damage and contamination, normal metabolic changes, and instability of its oil constituents when exposed to the atmosphere. To maintain its quality, more precise information is needed on the environmental factors which influence these changes during handling, storage, transportation and processing. Also, to insure uniform and standardized products in the marketing channels, new and improved methods for measuring quality factors need to be developed for use in inspection, grading and standardization programs.

### USDA PROGRAM

The Department has a continuing program involving textile engineers, cotton technologists, physicists, chemists, and engineers in basic and applied research on objective measurement and evaluation of quality of cotton fiber and on the quality evaluation and quality maintenance of cottonseed. The research is conducted at Washington, D. C., Lubbock, Tex., South Pasadena, Calif., and Clemson, S. C., in cooperation with Clemson University and by research contract with Clemson University, Texas Technological College, Auburn University, and Stanford Research Institute.

The program includes the following foreign projects under P. L. 480: A grant to Centre de Recherches des Industries, Rouen, France, provides for an investigation of fiber maturity and breakage during mechanical processing of cotton, and the relation of these factors to processing performance and product quality. Its duration is 4 years, 1961-1965, and involves P. L. 480 funds of $64,500 equivalent in French francs.

Another grant to the same institution provides for development of an instrument for homogenizing and orienting fibers in samples for cotton testing. Its duration is 4 years, 1961-1965, and involves P. L. 480 funds with a $47,000 equivalent in French francs.

A grant to the Fiber Research Institute, T.N.O., Delft, Holland, provides for a study of the influence of length properties on the mill processing performance of cotton. Its duration is 3 years, 1962-1965, and involves P. L. 480 funds with a $58,000 equivalent in Dutch guilders.

The Federal scientific effort devoted to research in this area totals 20.2 professional man-years subdivided as follows: Cotton 17.7, with 4.7 under research contract; and cottonseed 2.5.

Work terminated during the period included: Development of a small-scale spinning test to determine the spinning efficiency or spinning potential of cotton (MQ 3-1); and an evaluation of spinning and finishing performance of cotton as related to color grade according to the Universal Cotton Standards (MQ 3-13).

## PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

State stations are engaged in developing breeding stocks and varieties for both upland and long staple types of cotton. The influence of climate, cultural practices and harvesting, and storage conditions on yield and quality of fiber receives much research attention. Mechanical harvesting effects are evaluated by study of fiber properties and through spinning tests. Fiber samples from the breeding and cultural studies are submitted to state and Federal laboratories for testing of fiber and spinning properties. The Tennessee station is giving special attention to devising new and better tests and improving equipment for measuring properties now considered standard in fiber testing. One study is devoted to developing germination tests for cottonseed and measuring seed quality. Another deals with seed cotton moisture content and the effects on cotton fiber quality.

Cottonseed is evaluated for quality and nutritive value--of particular interest is the study of the chemical properties and biological significance of gossypol and gossypol protein complexes. The quality aspect relates to feeding value and quality of the meal for farm animals.

Approximately 12.1 professional man-years are devoted to quality evaluation of cotton and cottonseed.

## REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

### A. Objective measurements and evaluation of quality of cotton

1. Development of Small-Scale Spinning Tests. The processing of this study has been completed and a report submitted by Auburn University. Small-scale spinning tests developed show that the fiber length measurements are highly related to the spinnable limits value, and are related in general to ends down per 1000 spindle hours, as determined by large-scale spinning tests. The relationship is best when the spinning conditions of the large-scale spinning tests include fine yarns, low twist yarns, and/or high spindle speeds. The results indicate that at least two tests are needed for a reliable spinning performance evaluation; one to measure spinning performance under a normal condition and one at a more extreme condition. A procedure for small-scale spinning tests was developed and recommended. This project has been terminated.

(MQ 3-1(c))

2. Relation of Spinning Performance of Cotton to Color Grade. This research is being done under contract by Texas Technological College. The processing of this study has been completed and the data are being analyzed. Preliminary results indicate that, as the cotton grade decreased from strict middling white to low middling white and from the white to colored grades, the manufacturing waste increased, neps in card web increased, and spinning end breakage increased. The yarn strength did not seem to be related to grade but was related to fiber strength. Upon receipt of the report specified in the contract, the project will be terminated.

(MQ 3-13(c))

3. Evaluation of Interrelationship Between Cotton Fiber Measures. The first and most comprehensive manuscript in an expected series of several from this broad study has been reviewed by the editors of ARS, revised on the basis of their suggestions, and received approval for publication as a Marketing Research Report. This report is entitled "Interrelationship Among Five Cotton-Quality Factors, Including Fiber Strength 1/8-inch Vs. '0' Gauge As Related to Yarn Strength of Three Staple-Length Levels".

A second manuscript is in process of preparation and is entitled "Interrelationships Among Six Cotton-Quality Measures, Including Fiber Strength at Both The 1/8-Inch And '0' Gauge, As Related to Yarn Strength of Three Staple-Length Levels".

(MQ 3-17)

4. Effect of Various Production, Harvesting and Ginning Practices on Spinning Performance and Cotton Quality. These studies, in cooperation with other agencies, are being conducted by the ARS Cotton Quality Research Station, Clemson, South Carolina. The progress of these studies are as follows:

(a) Mill Performance Vs. Pilot Plant Performance. The processing of this study was completed by the Pilot Plant and by the three cooperative mills. The results indicate that even though the level of spinning end breakage varied among the mills and the Pilot Plant, the trend of end breakage for the spinning lots was very similar for the Pilot Plant and for two of the three mills. The lack of agreement in trends among all mills and the Pilot Plant may be due to the fact that the processing organizations differed. The data are being analyzed and a report will be made.

(b) S.R.I. Drier Vs. Conventional Drier. The processing of this study has been completed. The results indicate that the manufacturing waste was less and the spinning end breakage was lower for cottons dried to 6 percent with the S.R.I. drier than with the conventional drier when the original seed-cotton moisture was 13 percent. These differences between driers decreased as the original seed-cotton moisture decreased. The data are being analyzed and a report is being prepared for publication.

(c) 1962 Defoliation Study. This study was designed to determine the effects of defoliation, desiccation, irrigation management, and field exposure in conjunction with various gin cleaning levels on fiber properties and spinning performance. The processing has been completed. Preliminary analysis of the test results indicate that the differences in fiber and spinning qualities between undefoliated and defoliated or desiccated cottons were very small, although yarn strength was slightly higher and spinning end breakage was slightly lower for undefoliated cotton than for defoliated or desiccated cottons. This study included only early harvested cottons and it will be continued for a second year using both early and late harvested cottons.

(d) 1962 Alcohol Picker Spindle Study. This study was designed to determine the effects of an alcohol moistening agent for the picker spindle on harvesting performance, fiber and yarn quality, and

spinning performance of cotton. The results of this study indicated that the use of alcohol as a wetting agent on the picker spindle had no adverse effects on fiber and yarn properties. However, the spinning end breakage decreased slightly as the use of alcohol increased. The data are being analyzed and a report is being prepared.

(e) Moisture Restoration. This test was designed to study the effects of moisture restoration on the fiber and spinning qualities of cottons. For cotton from Mid-South and West, the results showed that lint ginned from seed cotton which had moisture restored between seed cotton cleaning and the gin stand gave better spinning performance, longer fibers, less short fibers, and a higher break factor than lint ginned from seed cotton dried with no moisture restored. A report is being prepared for this study.

(f) Mechanical Picker Spindle Study (Mississippi & California Cotton). The processing for the third crop year was completed. The results indicate that the trends established by previous studies are holding true for both Mississippi and California cottons; that is, (1) end breakage at spinning was less for hand-harvested cotton than for mechanically-harvested cottons and (2) that the type of picker spindle used in the mechanical harvester affected the level of end breakage. The data are being analyzed and a report is being prepared.

(g) Roller Gin Study. This study was designed to determine the effects of varying pressure on the roller gin flight bar had on fiber qualities and spinning performance when different roll speeds and roll diameters were used in ginning extra-long staple and long staple cottons. The processing was recently completed and the test results are being compiled. Preliminary analyses indicate only small differences in fiber and spinning quality for the Pima cotton. For the Acala 1517 cotton, the mean length, yarn uniformity, and spinning end breakage were adversely affected by increases in pressure on the roller gin. The effects of roll speeds and roll diameters are yet to be determined.

(h) 1963 Foreign Matter Study. This study was designed to determine the effects of foreign matter on spinning performance, production quality and cost of raw cotton. This study has not been processed.

(i) 1963 Bale Compression Study. This study was designed to evaluate the effect of different types of bale compressions on fiber quality and spinnability. This study will be processed under contract by the Texas Technological College.

(MQ 3-33)

5. Spinning Methodology Studies. The second methodology study was designed to study the effects of roving twist, spinning break draft and total draft on product quality and spinning performance. These results showed that, with other frame parameters constant, an increase in the total spinning draft caused only slight adverse changes in yarn strength and yarn uniformity but caused tremendous increases in spinning end breakage. Within the range of break drafts (1.4 to 3.0), a break draft of 1.4 produced the strongest and most uniform yarn but a break draft of about 2.2 produced the lowest level of spinning end breakage. The results of these studies are being used to gain information for the proper interpretations of spinning test results and to serve as a guide in selecting the spinning organizations to be used in the Pilot Plant for cottons of different characteristics. These methodology studies will be continued.

(MQ 3-33)

6. Investigation of Chemical Residues on Surface of Cotton Fibers. Further work was done on the development of test methods and procedures for the detection of chemical residues. Cotton samples from harvesting and ginning studies have been tested for moisture content, ash, pH, carbohydrates, sugars, oil contamination, pesticide and defoliant residues, inorganic elements, and for wax content. When the chemical test results were related to harvesting and ginning treatments, no relationship was found except for wax content. The amount of extractable wax found in samples subjected to high temperatures during ginning was slightly less than found for samples ginned without the use of heat in three of the ginning-spinning studies. However, the level of wax content between studies was greater than the differences due to heat within a study. These investigations will be continued, particularly in regard to the development of test methods and procedures for detecting chemical residues, etc.

(MQ 3-42)

7. Measurement of Frictional Properties of Cotton Fibers. An automatic method for measuring drafting cohesion and drafting-cohesion waves was developed and a manuscript describing the method was cleared for publication. A study of the effects of some fiber properties on roller drafting properties of cotton is in progress. Preliminary tests on several studies have indicated that drafting-force wave amplitude is highly related to fiber length variability.

(MQ 3-43)

8. Instrument Evaluation. The evaluation was continued for the fibrosampler and Digital Fibrograph combination designed to measure fiber length and length distribution. A progress report entitled "Evaluation of the Fibrosampler and Digital Fibrograph For Measuring Length and Length Distribution of Cotton Fibers" has been prepared. In this evaluation, it was

found that the Fibrosampler, as a sampling device, can be a very rapid and valuable instrument when properly used. The Fibrosampler tends to select long fibers; therefore, careful application is necessary in the type and preparation of sample. The Digital Fibrograph was found to be very stable when simulated samples were tested. Most of the variability in the testing of cotton samples is due to specimen differences. When length measurements by the Fibrograph and array methods are related to processing results, the test methods are about equal in predicting break factor and spinning end breakage. The Digital Fibrograph is currently being used to test samples in all ginning studies.

A Trashmeter was received for evaluation. This instrument was designed to measure very rapidly trash on the surface of cotton samples. Difficulty was encountered in the operation of the first instrument. The laboratory now has an instrument which seems to be stable and preliminary tests have been made. The evaluation of the Trashmeter will be continued, in cooperation with the Cotton Division of AMS.

(MQ 3-47)

9. Relationship of Fiber Maturity to Fiber Breakage During Mechanical Processing. A research project is being carried out in France under a P. L. 480 grant for an investigation of the relationship between fiber maturity and fiber breakage during the mechanical processing of cotton and the relationship of these factors to processing performance and product quality. The results from two bales of Acala 4-42 cotton representing two levels of maturity (Micronaire readings) indicated the following:

a. The more mature cotton had a longer mean length and a better length uniformity after the ginning process than did the immature cotton.

b. During textile processing (opening, picking, and carding), a certain amount of fiber is broken; however, a relation between fiber breakage and maturity could not be established.

c. The mature cotton produced yarns that were stronger, more uniform, and with less neps than did the immature cotton.

d. Spinning performance was much better for the mature cotton than for the immature cotton.

e. There does not seem to be any relation between the number of reversals in the fibriliar structure and maturity or length of fibers.

(59-AMS-4(a))

10. Instrument for Homogenizing Test Sample. Under a P. L. 480 grant, a research project is being carried out in France to develop an instrument for homogenizing and orienting cotton fiber in a sample for fiber testing. Several approaches to this problem have been studied but without success. Pneumatical and electrostatical means, separately and in combination, have failed in the separation of cotton fibers. One instrument developed using mechanical means (nylon brushes and rolls with metal clothing) did an excellent job in opening and separating the fibers but fiber damage due to breakage was too great to solve the problem of fiber breakage, two instruments are being developed and tested which will handle the fibers more gently. One instrument involves mechanical means only and the other a combination of mechanical and pneumatical.

(E9-AMS-5(a))

11. Influence of Fiber Length Distribution On Mill Processing. A research project is being carried out in Delft, Holland,under a P. L. 480 grant to study the influence of fiber length distribution on mill processing of cotton. The large-scale spinning for both the Acala and Deltapine cottons have been completed. The results show that the number of end breakage for the Acala variants were lower than for the Deltapine cotton. The trends obtained from the variants were the same for both varieties. The variant of the comber noil mix resulted in a significantly lower end breakage than for the variant of the cut fiber mix even though the fiber length distributions for the two mixes were practically identical and no essential differences in yarn properties were noted.

(E19-AMS-8(a))

B. Objective measurement of quality of cottonseed

1. Method for the Rapid Measurement of the Refining Loss of Cottonseed Oil in Small Lots of Seed. A study of refining losses of crude cottonseed oil and their possible correlation with conductivity measurements were carried out at several vegetable oil refineries. The results indicate that it is difficult to estimate refining losses with a single conversion factor. This is due to the difference in conductance of the three major compounds lost in the refining process - gossypol, free fatty acids, and phosphatides. The conductance of ammonium salts of gossypol are almost double those of free fatty acids salts and nearly 20 times that of the ammonium phosphatides.

To better understand refining losses in vegetable oils we are presently studying the simpler crude oil of soybeans. This oil does not contain gossypol and its major refining losses should therefore be mainly due to the free fatty acids and phosphatide content. Our studies have shown that more than 90% of the refining loss of soybean oil is due to its phosphatide content. The phosphatide range was found to be 0.5 to 5.0% with the majority of the samples falling between 2 and 3%. Free fatty acids content on the

other hand was found to be more constant, about 0.2% and with a smaller range of 0.2 to 0.4%. A possible conclusion from these observations is that it might be possible to estimate refining losses of soybean oil by determination of the phosphatide content rather than by a neutral oil determination with the phosphatide analysis being simpler and faster to perform than a neutral oil determination.

(MQ 3-45)

2. Re-evaluation and Improvement of Official Cottonseed Standards for Reflecting More Accurately the Value of Products Obtained from Cottonseed. The accuracy of the cottonseed grading system is dependent upon the accuracy of sampling procedures and methods of analysis of cottonseed and its products as well as their price relationships. During the past season a pneumatic method of sampling cottonseed was field tested (in cooperation with the Cotton Division, Agricultural Marketing Service and commercial interests) at two locations. This sampler is more rapid, less hazardous to operate and more accurate than the old official "corkscrew" type. It has been approved for use in the USDA Official Methods for Sampling, Analyzing and Grading Cottonseed, also approved by the National Cottonseed Products Association, and the American Oil Chemists Society. The new sampler will be in operation at plants of approximately one-third of all U. S. processors of cottonseed during the coming season.

A rapid method for determining oil in meal and cake was developed using the equipment employed in the rapid oil-in-seed assay. A modification of this method may also be used to determine oil in soybean meal. This rapid method will allow the processor to control his product more uniformly.

A study was made of price relationships of cottonseed and its products to oil-meal factors which will more accurately reflect the true value of the seed at different product price levels.

(MQ 3-51)

## PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

### Objective Measurements and Evaluation of Quality

Doughtie, R. T. Jr., and M. E. Whitten. 1964. A new cottonseed sampler. Agricultural Marketing. July.

(MQ 3-5)

Newton, Franklin E. and Samuel T. Burley, Jr. 1964. Fresh look at break drafts. Paper presented at Cotton Marketing Conference-Research Clinic, Pinehurst, N. C., February 1964 and published in Textile World, pp. 43-47. March.

(MQ 3-33)

Newton, Franklin E. and Samuel T. Burley, Jr. 1964. Spinning performance as influenced by fiber properties, yarn properties, and spinning frame parameters. Paper presented at ATMI Open House, Clemson, S. C., April 1964, at the Alabama Textile Operating Executives Meeting, Auburn, Alabama, July 23, 1964, and published in Textile Bulletin, pp. 40-44, June. (MQ 3-33)

Ross, John E. and Edward H. Shanklin. 1964. Effect of gin drying and cleaning of cotton on fiber length distribution and yarn quality. MRR-666-ERS-AMS-USDA July. (MQ 3-33)

Newton, Franklin E., E. W. S. Calkins, and A. C. Griffin. 1964. Fiber and spinning properties of cotton as affected by certain harvesting and ginning practices. MRR-656-AMS-ERS-ARS-USDA June. (MQ 3-33)

Shanklin, Edward H. and Robert A. Mullikin. 1964. Effect of cotton ginning practices on cotton yarn properties, weaving performance and fabric properties. MRR-655-AMS-USDA May. (MQ 3-33)

Mullikin, Robert A. and Frances Carpenter. 1964. How combed yarn mills can use span length measurements. Paper presented at the Textile Quality Control Association Meeting, Clemson, S. C., September. (MQ 3-47)

Whitten, M. E. and L. A. Baumann. 1963. Evaluation of a rapid method for determining oil content of cottonseed. USDA Tech. Bul. 1298. (MQ 3-5)

## MARKETING FACILITIES, EQUIPMENT AND METHODS
## Transportation and Facilities Research Division, ARS

Problem. Differences in varieties of cotton and in the environments of producing areas where it is conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to the efficient and economical handling, conditioning, storing, and maintaining quality. There is a need for improved designs for facilities based on functional and structural requirements, which will expedite the movement of cotton into, within, and out of the facility. There is also a need for handling and conditioning equipment which will minimize labor and other costs. More knowledge is needed of the relative efficiency of various handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

### USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving agricultural engineers and industrial engineers engaged in both applied and basic research on, as well as application of known principles to, the solution of problems of handling, storing, and conditioning field crops in marketing channels. Research on the handling of cotton bales and humidification of storage compartments is conducted at Bakersfield, California, in cooperation with Calcot, Ltd., at selected warehouses in California and Arizona. Research on aeration and storage of cottonseed is conducted at Stoneville, Mississippi, in cooperation with the Mississippi Station and at commercial facilities in Mississippi.

The Federal effort devoted to research in this area during the fiscal year 1964 totaled 17.4 professional man-years; of which 1.0 is devoted to the handling of bales of cotton and to the humidification of cotton storage compartments; and 1.0 to the aeration and storage of cottonseed.

### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Aeration and Storage of Cottonseed

At Stoneville, Miss., studies were continued in both commercial storages and in the laboratory to determine the usefulness of aeration for maintaining the quality of cottonseed in storage for both short term and long term storage. The studies include the determination of satisfactory airflow rates, equipment requirements, size and location of ducts, operating schedules, and labor requirements for aerating stored cottonseed.

During the 1963-64 storage season one improved aeration system was designed and installed in a cooperating commercial storage. With the improved system less than one fourth the electric power used the previous season in the same storage was required to move more air through more cottonseed and at

a greater depth. A part of the improved system was an aeration duct having a greater percentage of surface area that limited the velocity of the air moving through the cottonseed and into the ducts. This increased surface area was responsible for a major reduction in static pressure losses in the cottonseed around the duct. This, plus the use of more efficient fans and well designed air supply systems, was responsible for most of the increase in the performance efficiency of the improved aeration system.

Laboratory studies were initiated to determine the effects of different duct surface areas and materials and of compaction of stored cottonseed on static pressure losses when moving air through the seed. One series of tests was conducted using two types of duct sections and air velocities of 5, 10, 15, 20, and 25 feet per minute at the duct surfaces. These limited tests indicate that both the type and area of duct surface affect the static pressure losses in the seed immediately surrounding the duct.

Studies of the small-scale aeration system installed last year were continued. The data obtained were too limited to indicate any definite cooling rates for the airflow rates used--1/10, 1/5, 1/3, and 1/2 cfm per cubic foot of cottonseed. When cottonseed having an initial moisture content of about 8 percent was aerated with air at relative humidities above 75 percent and temperatures below 55°F., its moisture content was increased about 1 1/2 percent.

B. Handling Cotton Bales and Humidifying Storage Compartments

1. Handling Cotton Bales. At Bakersfield, Calif., studies were continued on the use of 10,000-pound clamp trucks for unloading bales from one side of a road truck. With flat bales loaded 2 high on head on a truck, one 10,000-pound clamp truck carrying 12 bales per trip can unload 100 bales and set them in row blocks ready for tagging, sampling, and weighing in 20 minutes. This is a saving of around 15 minutes over the next best method where a 4,000-pound clamp truck is used. Some states do not permit road trucks to travel with bales stacked 2 high on head, but require that the top tiers be in a horizontal position. Therefore, studies are being continued to develop unloading methods for the required loading patterns.

The installation of equipment was not completed for the study of the electronic transmission of bale weights, etc., so tests could not be initiated during this reporting period.

Limited observations of conveyors used for moving bales from the dinky press to the compress indicated that production was relatively low and maintenance costs relatively high. Additional work is planned for this phase of bale handling operations.

The report comparing the use of tractor-trailer trains and 10,000- and and 18,000-pound clamp trucks for transporting bales was submitted for clearance for publication.

Two reports were published during the year. "Weighing Bales of Cotton at the Compress" compares an electronic scale in combination with an automatic dinky press feeder with two current methods using portable platform scales. "Increasing Storage Capacity in Older Cotton Warehouses" suggests ways of modifying layouts and stacking patterns in old warehouses to increase their capacity and to make it possible to use modern handling methods.

2. Humidifying Storage Compartments. At Bakersfield, Calif., research was initiated to determine the feasibility of humidifying storage compartments to maintain the moisture content of stored bales of cotton at a desired level and to minimize the normal loss of moisture which increases the brittleness of the cotton fibers. Bales having an initial moisture content of about 5 percent were stacked in three patterns in a controlled test room and in a compartment with some humidification. Relative humidity of the air in the control room was maintained at 80 percent, corresponding to cotton moisture of about 8 percent. During the winter with outside temperatures between 38° and 50°F., the moisture content of bales, in both the control room and the compartment, reached 7 percent in 30 days and 8 percent 20 days later. This moisture level was maintained for 200 storage days in the compartment, or until the outside air temperature rose to 90°F. and humidity lowered to 15 percent, at which time compartment humidifiers were operated continuously. This resulted in the compartment bales increasing to 8.5 percent moisture content, then reducing sharply to 6.5 percent as temperatures rose to 100°F. Bales in the control room remained at about 8 percent moisture during the test period. In both the test room and the compartment, changes in moisture at the center of the bale lagged changes near the surface by 2 to 3 weeks. Bale stacking patterns showed only a slight effect on moisture change. Bales in the control room followed the same trend in moisture change regardless of bale density or storage position, however the rate of change was faster in low density bales. Studies will be continued using various bale coverings and stacking patterns and cotton of identical history. Tests on the effect of humidification on cotton quality will be included.

C. Consumer Packages and Shipping Containers

In November 1963, an administrative report on all-cotton covers for U. S. cotton bales was prepared in cooperation with Cotton Division, AMS. The all-cotton covers used for the 1962 crop were compared with three types of jute covers commonly used in this country. The all-cotton covers weighed 12 pounds and were priced at $4.80 per bale. The various jute covers were approximately the same weight, but their prices averaged $1.54 per bale. Mixed shipments of bales were checked at gins and some were traced through shippers' warehouses and opening rooms at domestic textile mills. The all-cotton covers were neater in appearance, had less tearing and raveling, and stripped off more easily than the jute covers, leaving a cleaner surface on the opened bale. Information obtained was insufficient to quantify handling advantages for gins, shippers, or mills.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Aeration and Storage of Cottonseed

Smith, L. L. 1964. Aeration of cottonseed facilities. Mississippi Farm Research.

Smith, L. L. 1964. Cottonseed storage and aeration in commercial facilities. Mississippi Agricultural Experiment Station. 77th Annual Report for Year Ending June 1964.

Handling Cotton Bales

Bolt, C. D. 1964. Weighing bales of cotton at the compress. AMS 534. 19 pp.

Bolt, C. D. 1964. Increasing storage capacity in older cotton warehouses. AMS 535. 23 pp.

## ECONOMICS OF MARKETING
Marketing Economics Division, ERS

Problem. The structure, location, and marketing practices of the fibers industry are undergoing pronounced changes which are important to producers, marketing agencies, and consumers. The rapidity and magnitude of these changes have resulted in some serious marketing problems. The causes and results of these changes need to be better defined and evaluated to provide a more adequate basis for increasing the efficiency of the marketing system and emphasis is needed on changes in the structure and practices of the fibers industry and product quality. In addition, increased emphasis should be placed upon defining the important quality characteristics of the various fibers in relating this information to differences in value or price. Such an accelerated program would provide more complete and current information not only to producers and marketing agencies but also to officials responsible for public programs affecting agriculture and to teachers and extension workers.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of economic research in fibers marketing which attempts to reach from the farm to the consumer. Most of the research is problem solving in nature, and is conducted by economists or personnel with both economic and technical training. In nearly all studies, close cooperation is maintained with industry and trade groups and with private firms that generously provide essential data and make plant facilities available for observation.

In fiscal year 1964, the Division devoted 12.3 professional man-years to the study of structure, practices, and competition; product quality; margins and efficiency; and information, outlook and rural development of cotton and cottonseed products.

### PROGRAM OF STATE EXPERIMENT STATIONS

Over two-thirds of the projects in cotton marketing research are contributions to regional studies in which Federal agencies are cooperating. Presently the research is directed largely to three main marketing functions. Over two-thirds of the studies are concerned with analysis and evaluation of actual market forces and performance in channels of trade with emphasis on potentials for more efficient marketing systems than now prevail. About 20 percent of the studies are concerned with effects of handling practices for lint and seed cotton on quality factors affecting grades. An equal number of studies emphasize factors affecting costs and operating efficiencies in gin operation and on handling practices of cotton at the gin.

Total research effort on cotton marketing at the nine stations is 10.7 professional man-years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

### A. Structure, Practices, and Competition

1. Pricing Cotton in Relation to Fiber Properties. United States' cotton's competitive position would be enhanced by an appropriate pricing system which would more accurately reflect its true use value. A report to be published in early 1965 supports the preliminary findings reported last year. Continuing checks on the market situation were made during the year to provide a basis for recommendation for incorporation of fineness differentials on loan prices.

2. Marketing and the Use of Cotton Waste. Marketing and processing cotton waste is a multi-million dollar business. Although numerous end products are manufactured from this valuable byproduct of the cotton industry, requiring the services of a wide variety of firms, there is little specific knowledge available on source, quality, and utilization of waste and on marketing and pricing practices. Since initiation of this project in May 1964, plans for the collection of data on market organization and structure and marketing practices and procedures have been finalized. Tentative plans for conducting two succeeding phases of work have also been developed.

3. Cotton Bagging. Improved packaging of other commodities in recent years, and the growing competition from synthetic fibers and foreign cotton with their better package, have focused better attention on the unfavorable aspects of the American cotton bale package. The feasibility of replacing the present jute covering with one made of cotton was investigated. The results indicate that a cotton covering is more satisfactory to shippers and mills but costs about 3 times as much as the jute covering. This study was conducted in cooperation with the U.S. Agricultural Research Service and they prepared a report incorporating their results.

### B. Product Quality

1. Changes in Quality and Value of Cotton Bales and Cotton Samples During Storage. Changes in quality of cotton during storage lower market values and necessitate frequent resampling of bales with attendant increases in cost. In addition, the practice of cutting samples from cotton bales results in contamination of the fiber, and increases the risks of fire damage. These disadvantages could be offset through acceptance of automatic sampling. Information was needed on the extent and nature of quality changes in stored bales, the feasibility of using stored samples for evaluating these quality changes, and the usefulness of automatic samples for determining market value of cotton. This study was undertaken in cooperation with U.S. Agricultural Marketing Service.

2. Economic Evaluation of Cotton Quality. Certain cotton production, harvesting, and ginning practices which appear to lower cost or increase prices to producers result in damage to the fibers, which increases manufacturing costs, decreases the quality and value of textile products, and impairs the competitive position of U.S. cotton. Measures of the effects of these practices are needed as guides for efficient adjustments in the cotton industry. Recently completed analysis of the combined effects of defoliation and gin cleaning on El Paso cotton shows that premature defoliation was associated with only .2 of a unit lower average micronaire reading; 90 units lower yarn break factor; 6 points lower yarn appearance index; and .35 percentage point more manufacturing waste than the normal or nondefoliated cotton. However, defoliated cotton was 1/32 to 1/16 inch shorter. Minimum cleaning produced somewhat lower grade and market value but longer, more uniform fibers which had substantially lower number of neps in carding and higher yarn break factor than cotton receiving maximum cleaning. Tests on cotton from other areas completed during the past year indicate similar results. Reexamination of length distribution data from previous tests, indicates that the reduction in long fibers resulting from extreme drying and cleaning practices usually is accompanied by changes in the length of cotton in all other categories with, generally, a somewhat less proportionate reduction in medium lengths but a very substantial increase in short lengths. This study is a cooperative undertaking with Clemson Agricultural College and U.S. Agricultural Research Service.

C. Margin, Cost and Efficiency

1. Charges and Practices in Marketing Cotton. Frequent changes in the costs and organizational structure of the cotton industry require that up-to-date information be available on charges to producers for ginning and selected marketing functions and on trends for related services. In the 1963-64 season the Beltwide charge for saw ginning and wrapping a 500-pound bale of cotton was $16.80--a decrease of 28 cents per bale from the previous season. Improved turnouts contributed to the lower average charge. A 500-pound bale required 1,388 pounds of handpicked seed cotton, 1,952 pounds of handsnapped, 1,476 pounds of machine-picked, 2,214 pounds of machine-stripped, and 2,389 pounds of machine-scrapped. The proportion of upland cotton harvested by machine increased 2 percent during the 1963-64 season. Beltwide, 51 percent was machine-picked, and 1 percent machine-scrapped for a total of 72 percent mechanically harvested. Charges by public warehouses averaged 74 cents per bale for receiving and 51 cents per bale per month for insured storage in 1963-64, about the same as in the previous season. The study was undertaken in cooperation with U.S. Agricultural Marketing Service.

2. Marketing Margins and Costs for Fibers and Textiles. Information on the competitive position of American cotton and wool; marketing margins and costs for cotton, wool, manmade fibers, and textile products is needed as a basis for appraising the present position of the industry and to indicate means of improvement. Data from a completed study indicate that market outlets for

American cotton and wool continue to be adversely affected by increased competition from other fibers. Costs of ginning and merchandising cotton continued to increase to 1963. Margins for wholesale and retail distribution of textile products have increased since 1947, averaging 41 percent of the consumer's dollar in 1962.

3. Cotton Ginning Efficiency and Cost. Additional cleaning equipment in gins necessitated by increased mechanical harvesting, declining volumes in some areas, and rising cost of variable inputs have resulted in a sharp upward movement in average ginning costs and created an urgent need for reliable information designed to increase ginning efficiency in each major production area. Several phases of work were pursued during the past year under this project. Results indicated that substantial savings in power costs could be realized by peaking the efficiency of individual air systems used for materials handling, by rearranging gin machinery to eliminate unnecessary fans, motors, and piping, and properly loading electric motors. Results also indicate that under present market conditions most ginners can profitably reclaim their gin motes. In addition, more efficient use of labor could reduce cost per bale between 13 to 33 cents per bale in the selected areas studied. Work was initiated to determine the economic advisability of increasing ginning capacity by storing seed cotton. Cost data from long staple gins in Arizona and New Mexico were collected to supplement data required for the proposed development of model gins.

4. Cost and Efficiency of Warehousing and Related Services for Cotton. Rising costs at cotton warehouses and increased stocks of Government-owned cotton give added importance to the need for information on the cost of operating cotton warehouses. Research designed to provide this information is underway.

D. Information, Outlook, and Rural Development

1. Central Market Quotations for Cotton and Factors Affecting Their Adequacy. Departmental responsibility for providing cotton price information which is adequate for use in cash and futures trading and in the operation of the price support program requires periodic evaluation of the adequacy of the basis for and accuracy of central market quotations.

## PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

### Cotton and Cottonseed

Cable, C. C., Jr., Smith, H. R., and Looney, Z. M., Feb. 1964, Changes in Quality and Value of Cotton Bales and Samples During Storage, MRR 645, pp. 58

Cable, C. C., Jr., Smith, H. R., and Looney, Z. M., April 1964, Comparison of Mechanically Drawn Samples with Cut Samples for Evaluating Cotton Quality, MRR 654, pp. 28

Ross, J. E., and Shanklin, E. H., July 1964, Some Effects of Gin Drying and Cleaning of Cotton on Fiber Length Distribution and Yarn Quality, MRR 666 pp. 12

Calkins, E. W. S., Newton, F., and Griffin, A. C., June 1964, Fiber and Spinning Properties of Cotton as Affected by Certain Harvesting and Ginning Practices, Yazoo-Mississippi Delta, 1959-60 (published by AMS) pp. 27

Howell, L. D., Nov. 1964, The American Textile Industry--Competition, Structure, Facilities, Costs, Ag. Econ. Rpt. 58, pp. 146

_____ May 1964, Charges for Ginning Cotton, Costs of Selected Services Incident to Marketing, and Related Information, Seasons 1963-64, ERS-2, USDA, pp. 1

Wilmot, C. A., and Alberson, D. M., March 1964, Increasing the Efficiency of Power Used for Materials Handling in Southwestern Cotton Gins, ERS-154, pp. 18

Holder, S. H., and Looney, Z. M., May 1964, Reclaiming and Marketing Cotton Gin Motes, ERS-168, pp. 14

Holder, S. H., and McCaskill, O. L., Oct. 1963, Cost of Electric Power and Fuel for Driers in Cotton Gins, Arkansas and Missouri, ERS-138, pp. 12

Watson, H., Griffin, A. C., and Holder, S. H., Jan. 1964, Power Requirements for High Capacity Cotton Gins in the Yazoo-Mississippi Delta, ARS 42-94, pp. 14

Pritchard, D. L., and Potter, J. R., Jr., May 1964, The Traffic Pattern of Raw Cotton Shipped from Warehouses in the United States, 1961-62, ERS-184, 34 pp.

Ross, J. E., May 1964, Trash as a Factor in Costs and Mill Performance, Speech published in Summary Proceedings, Cotton Marketing Conference-Seminar, National Cotton Council, Hot Springs, Ark.

## COOPERATIVE MARKETING
Marketing Division, FCS

Problem: Farmers are expanding their use of cooperative marketing. There are constant changes in transportation, processing, and distribution technology, and in market organization and practices, and changes on the farm itself. In view of these developments, farmer cooperatives and other marketing firms require research results to perform both efficiently and effectively. Such research can assist farmers to maintain and strengthen their bargaining power, increase efficiency, and meet the quality, quantity, and service needs of today's food and fiber marketplace.

Cooperative marketing is a major way for farmers to get maximum returns from their products in the current and rapidly changing market. Farmers own and control cooperatives specifically to increase their income from crops and livestock. Gains are not automatic, however. Cooperatives must plan, develop, and actually manage the specific marketing program and services that will yield the most for their members. Marketing cooperatives must know what the market demands. They must be able to compute the probable cost of different ways of serving the market. They must understand the possibility of major economies in a well coordinated joint sales program, and understand the methods and potentials of bargaining. Management must achieve minimum costs through improved organization, good use of existing plant and personnel, and the selection and use of new equipment and methods.

### USDA PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation, and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D.C. Many of the studies, however, are done in cooperation with various State experiment stations, extension services, and departments of agriculture.

Federal professional man-years devoted to research in this area totaled 23.3 of which 2.7 man-years are devoted to cooperative marketing of cotton.

### STATE EXPERIMENT STATIONS PROGRAM

The State stations maintain a very broad research program in commodity marketing, the findings of which are valuable to cooperatives and to other marketing firms. There are at this time nine projects in eight States that deal specifically with cooperative marketing. These projects seek to find out how cooperatives are adjusting or might better adjust to changes in market structure and marketing practices. In some instances, researchers are

studying the success and failure of cooperatives and the organizational structure. One study of the history of major cooperative marketing associations in the State will be published as a book and will undoubtedly receive nationwide attention.

The total research effort on cooperative marketing in the eight States is 3.4 professional man-years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

### A. Cost and efficiency

1. Cotton. Analysis was made of ginning costs for central gins with receiving stations. It was found that ginning costs could be reduced about $5 a bale, and that the value of cotton could be improved through blending, perhaps by about $5 a bale. Operating costs and revenues of cottonseed oil mills were analyzed. Findings help operators to locate inefficient features of their operations. Analysis of the oil flow pattern in cottonseed and soybean oil mills gave information suggesting more efficient marketing and transportation of oil.

### B. Improving operating methods in processing and storage

1. Cotton. Research was completed on how much chemical lint to remove from cottonseed under varying linter prices. Findings give guidelines for mills to use, applying their own costs and revenues of delinting, in determining how much linters to remove. Another study was underway to develop recommended changes in operations and organizational setup of cotton cooperatives in west Texas. Research continued on economic effects of storing seed cotton in baskets at gins.

## PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Bradford, H. W. 1964. Cotton Co-ops Point Way to Progress. News for Farmer Cooperatives (Jan.).

Campbell, J. D. 1964. Costs of Ginning Cotton by Cooperatives at Single-Gin and Two-Gin Plants, California and Texas, 1962. Marketing Research Report 640.

Campbell, J. D. 1964. Economics of Baling and Storing Seed Cotton for Processing at a Central Gin. FCS Service Report 67.

Campbell, J. D. 1964. Multiple vs. Single Cooperative Cotton Gins. News for Farmer Cooperatives (May).

## ECONOMIC AND STATISTICAL ANALYSIS
Economic and Statistical Analysis Division, ERS

Problem. Because of the instability of the prices he receives and rapidly changing conditions of agricultural production, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for sound production and marketing decisions. It has long been a goal of the Department to provide the farmer with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting the principal farm commodities.

Producers, processors, distributors and consumers need better information on supplies, production and consumption of farm products, and the effect of these and other factors on the prices of these products. Similarly, Congress and the administrators of farm programs need to evaluate alternative proposals to modify existing price support and production control programs in terms of their impact on production, consumption and prices received by farmers.

The needs of all these groups require more accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products. Farmers need to know the prices they may expect from different levels of production in order to plan for maximum returns. Cooperatives, processors and distributors need adequate statistical information on price and consumption responses under different supply conditions to aid in distribution of agricultural supplies that lead to maximum returns to farmers.

### USDA AND COOPERATIVE PROGRAM

#### The Commodity Situation and Outlook Analysis

Cotton and Man-Made Fibers. This work involves 1.5 professional man-years in Washington. The outlook and situation program provides a continuing appraisal of the current and prospective economic situation of cotton. These appraisals and results of special studies are published 6 times a year in the Cotton Situation, and quarterly in the Demand and Price Situation. A comprehensive analysis of the cotton and man-made fibers situation is presented at the Annual Outlook Conference. Outlook appraisals are frequently presented at regional or State outlook meetings, at meetings of farm organizations, and to various agricultural industry groups. Special analyses are prepared on the probable effect of proposed programs on the price, supply and con-

sumption of cotton and man-made fibers and textile products. Basic statistical series are developed, maintained, improved, and published for general use in statistical and economic analysis. A Handbook, Statistics on Cotton and Related Data, is published annually.

Supply, Demand and Price of Agricultural Commodities

Cotton and Other Fibers. This work involves 1.5 professional man-years located in Washington, D. C. The purpose of this research program is (1) to measure the influence of economic factors that affect consumption of major textile fibers, and (2) to measure the economic factors that affect the price, supply, and utilization of cotton and cotton products. A major effort during the past few years has been the development of analyses to forecast domestic consumption of cotton, wool, and other fibers. The other major outlet for raw cotton has been exports. Factors causing variation in exports are being examined and quantitative relationships will be developed to be used for forecasting exports of raw cotton. These, along with the equations for forecasting domestic consumption, will improve forecasts of the total utilization of cotton.

## PROGRAM OF STATE EXPERIMENT STATIONS

For the most part, the States depend upon the United States Department of Agriculture for the yearly across-the-board commodity situation and outlook research. The State extension staff members supplement and adopt such research information to meet the commodity situation of their States.

The States are engaged in intensive and extensive research in price analysis. Much of it is of a basic nature to gain an understanding of price-making forces. Most of this research is commodity oriented, though some projects are of a highly mathematical and theoretical nature aimed at improving price analysis methodology.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Commodity Situation and Outlook Analysis

A comprehensive study, released in November 1963, developed estimates of final domestic textile fiber consumption in the United States and identified the major economic factors affecting variations in fiber consumption. The new estimates of consumption take into account shifts in U.S. exports and imports of textiles and the change in composition of fibers used by domestic mills.

An article in the March 1964 issues of the Cotton Situation examined the production of fabric blends in the United States. In recent years, the production of blends has increased sharply even though total fabric production has risen only slightly. For example, production of fabrics from

blended yarn of blends of two or more fibers increased more than 50 percent from 1958 to 1962, while non-blended production increased less than 2 percent. Cotton fabric blends increased by over 70 percent compared with a rise of 2 percent for non-blended fabric. Blends where cotton represents the minor fiber have shown the sharpest rise. Further research is needed to measure the full impact of fabric blends on cotton consumption.

Special analyses were prepared for the Secretary's office on the probable effect of various proposed programs on the price, supply, and consumption of cotton. After passage of new legislation, special studies have included the probable effect of changes in mill costs of raw cotton on both wholesale and retail prices for cotton textiles. With a price change in raw cotton, most of the effects at the wholesale and retail level were found to occur several months later. Extensive data and analyses were furnished to the Secretary of Agriculture's Advisory Committee on Cotton and to the National Advisory Commission. Data on use of fibers by the military forces were revised and updated. An annual supplement to a basic statistical handbook, including data for 1963-64, was published. Data were compiled for publication of a basic statistical handbook for extra-long staple cotton. Projections of production and utilization of cotton for 5 years ahead were revised and updated.

B. Supply, Demand and Price of Agricultural Commodities

A technical bulletin released in November 1963 developed estimates of final domestic textile fiber consumption in the United States and measured the effect of the major economic factors on variations in consumption. Highlights of the results were presented during the last reporting period. Results from this study are being used in special analyses on probable effect of changes in mill costs of raw cotton on both wholesale and retail prices of textiles.

Work on price and utilization of cotton and cotton textiles was continued, and a manuscript is being prepared, with separate statistical analyses to isolate the important factors in all major outlets. Results of analyses indicate that the level of U. S. prices in foreign markets and changes in foreign production and consumption of cotton and synthetic fibers have the most effect on U. S. cotton exports.

Results from statistical analyses also indicate that total production of cotton in foreign countries is influenced by the level of world cotton prices. Consumption abroad has risen in response to rising standards of living and increases in population. Changes in world cotton prices were found to have a significant effect on consumption. Additional analyses are underway to determine the effect of various factors on cotton consumption and production in major individual foreign consuming countries.

Exploratory analyses were made of the demand for groups of fabrics in the United States such as print cloth, sheeting, and narrow fabrics, to gain insight into the domestic utilization of cotton. Special attention was given to the sharp increase in use of man-made fibers and production of broad woven goods.

Estimates of fiber used by the military services were revised and updated. Also, conversion factors for estimating the raw fiber content of U. S. exports and imports of textiles are being revised, and analysis is being made of recent changes in U. S. trade in cotton manufacturers.

## PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

### The Commodity Situation and Outlook Analysis

#### Cotton

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### Supply, Demand, and Price of Agricultural Commodities

#### Cotton and Other Fibers

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## CONSUMER PREFERENCE AND QUALITY DISCRIMINATION-- HOUSEHOLD AND INDUSTRIAL

Standards and Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for consumers to express to producers either pleasure or displeasure with available merchandise. To market agricultural products more effectively, it is necessary to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on consumers' attitudes toward old and new product forms of agricultural commodities, preferences, levels of information or misinformation, satisfactions or dislikes, and what product characteristics would better satisfy current consumers and/or attract new ones. It is also important to know the relationship between the consumption of one agricultural commodity and another in consumers' patterns of use, the relationship between agricultural and nonagricultural products, and probable trends in the consumption of farm products. Producer and industry groups as well as marketing agencies consider such information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increases returns to growers.

### USDA PROGRAM

The Special Surveys Branch conducts applied research among representative samples of industrial, institutional, or household consumers and potential consumers. Such research may be conducted to determine preferences, opinions, buying practices, and use habits with respect to various agricultural commodities; the role of competitive products; acceptance of new or improved products; and consumers' ability to discriminate among selected attributes of a product or levels of an attribute, and the preferences associated with discriminable forms. The research is carried out in cooperation with other USDA or federal agencies, State experiment stations, departments of agriculture, and land grant colleges, and agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D. C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch. The federal scientific effort devoted to research in this area during the past year totaled 7.0 professional man-years under regular program funds, of which .7 professional man-years are engaged in studies specifv on cotton.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Fibers in wearing apparel. The rapid expansion in recent years in the use of manmade fibers and blends necessitates up-to-date evaluations of consumer reactions to natural fibers in specified end uses. Such data give industry a better understanding of its markets, and provide a guide for planning physical science research on product improvement as well as educational, promotional, and merchandising efforts designed to strengthen the market position of cotton and wool.

A contract has been signed with a market research firm for a nationwide survey among women to provide current information on their experiences, beliefs, attitudes, and complaints related to natural and competing fibers in selected items of clothing. The Department and the cotton and wool industries, in an effort to meet the increasing competition from manmade fibers, have developed new forms of materials in recent years (for example: improved wash-and-wear, wrinkle resistant, permanently creased, and stretch cotton; and machine-washable and permanently creased wool); consumer reactions to these new developments will also be assessed.

A preliminary report on the results of a contract study of reactions to fibers in clothing among a nationwide sample of teenage boys and girls was issued during the Fall of 1964; a final report presenting more detailed findings is in preparation.

The preliminary results indicate that wool was the leader in ownership and preference for winter skirts, boys' sport coats, and boys' and girls' sweaters and outer short coats. Warmth was the main attraction of wool, although its ability to withstand wrinkles, to hold its shape, and its soil resistance were also frequently mentioned as reasons for preferring it over other fibers. Cotton was the leader in summer clothes for both boys and girls. It was the winter favorite as well among boys for everyday pants and sport shirts and among girls for everyday dresses and blouses. Comfort was the main attraction of cotton, winter or summer; that is, it did not irritate the skin, it was cool in the summer, and warm enough or not too warm in the winter. In addition, girls stressed the ease of washing and ironing cotton as a reason for preferring it over other fibers.

Cotton-polyester was important in summer wear for girls and boys. The teenagers who preferred it gave, for the most part, the same reasons for their preference as those who chose cotton. However, cotton-polyester had the added attraction that it did not wrinkle. Nylon was the most frequently owned and preferred fiber for girls' slips and half-slips, mainly because of the ease in care and laundering. Acrylic fibers were important, after wool, either alone or in blends, in winter sweaters. Those who preferred acrylic in sweaters did so because it did not irritate the skin, held its shape, and, of especial importance to girls, could be easily washed.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Owings, Ann Sept. 1964. Young People's Use and Appraisals of Natural and Competing Fibers Used in Wearing Apparel - A Preliminary Report. Bulletin SRS-4 (S&R 3-1)